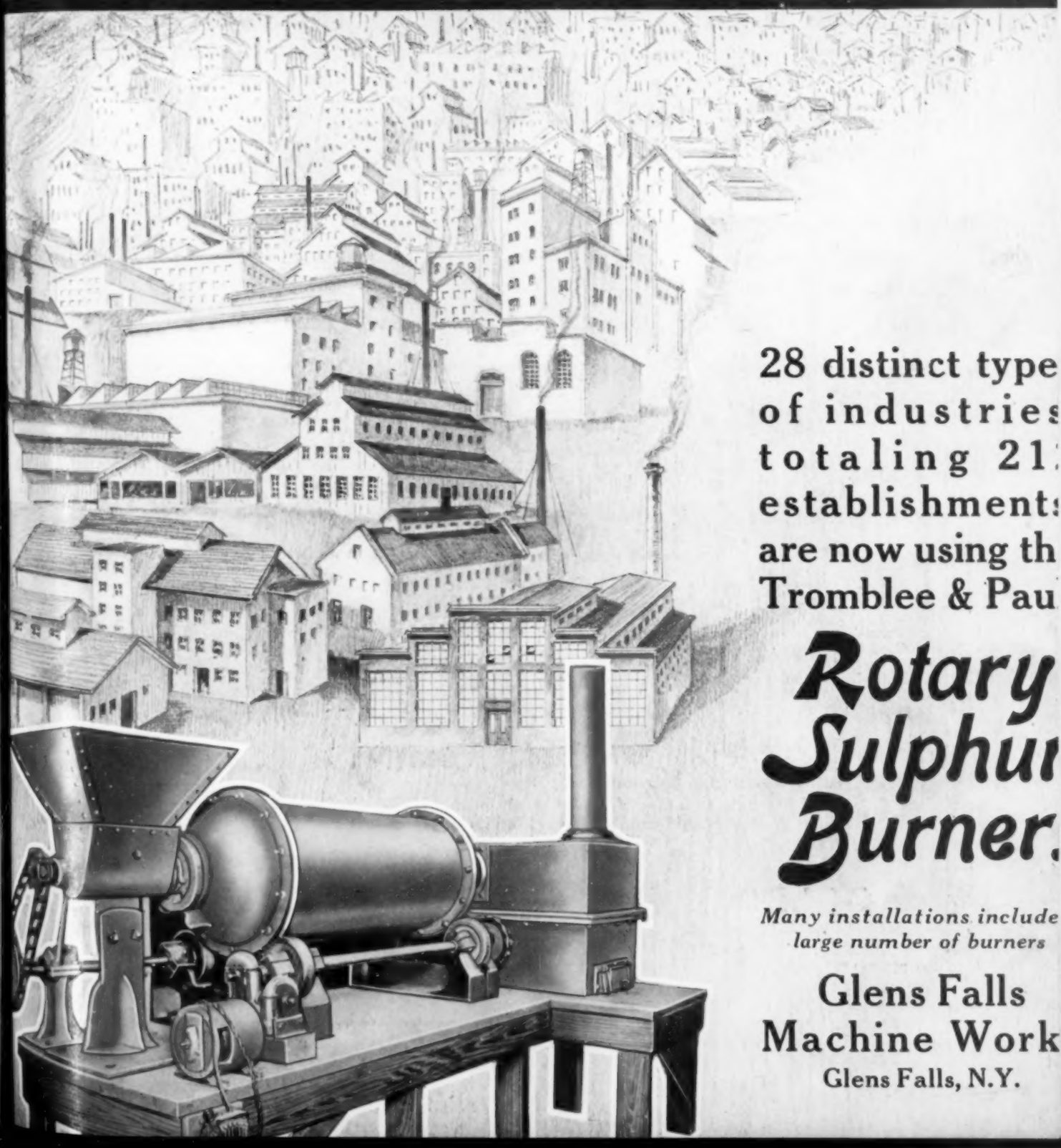
A Semi-Monthly Technical Newspaper

Metallurgical & Chemical Engineering

Volume XIV, Number 12 June 15, 1916 McGraw Publishing Co., Inc.



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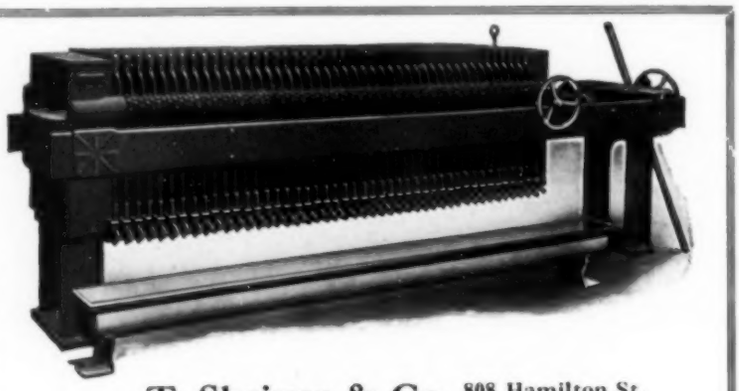

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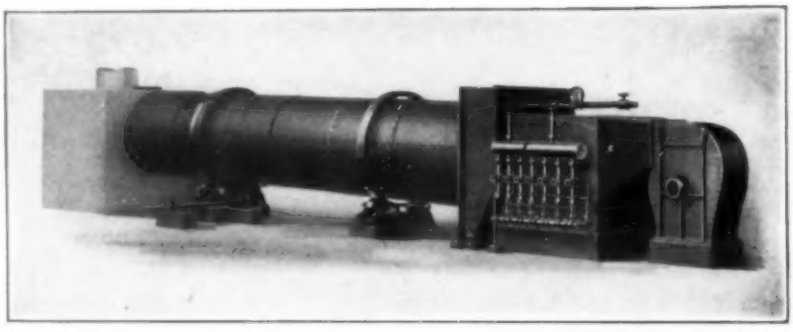

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103 Richmond St. W., Toronto, Ont.

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIV | NEW YORK, JUNE 15, 1916 | No. 12

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH OF EACH MONTH BY THE

McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer
239 West 39th St., New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.
ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Col.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
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J. MALCOLM MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $3.00; all other countries, $4.00.

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Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

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The Semi-Annual Index

As long as this journal was a monthly, the twelve issues of a year comprised one volume. The change to a semi-monthly has made it necessary to divide a year's contents into two volumes in order to keep the size of a volume within reasonable limits, and an alphabetical index will be published with the last number of each volume. Accordingly the present issue concludes our fourteenth volume and bound into this issue will be found our first semi-annual index.

The Slump in Tungsten

The inevitable slump in the tungsten market has come. It came quickly, and apparently to the surprise of those most concerned, viz., the small producers who naturally were the optimists and perhaps blinded to or ignorant of the economic situation. Outsiders generally had regarded the tungsten market as the most precarious of the metal markets that had been stimulated by the war.

Never before had the tungsten business been so profitable; always it had been erratic, experiencing first a fat season and then a lean one. With the sudden demand created by the war, prices soared to unexpected heights, and while at first producers could scarcely believe their good fortune, they later seemed to become inoculated with the idea that prices would go still higher and hold for a year or more.

The slump resulted primarily from natural causes—the development of an adequate supply from new and obscure or dormant sources, brought forth by attractive prices. It took some time to stimulate that supply, but when it became visible it loomed suddenly large. Boulder County, Colorado, had been regarded, and justly so, as the principal tungsten field in this country, for in 1913 it produced the equivalent of 953 tons of 60 per cent WO_3 concentrate, which was 62 per cent of the total domestic output and perhaps 12 per cent of the world's production. In 1914, however, first rank was taken by the Atolia field in the Mohave Desert of California, and Boulder dropped to second place with an output of only 467 tons, or 47 per cent of the domestic output. The year 1914 was not particularly favorable for tungsten production, which probably accounts for Boulder's loss of prestige. In the early part of the year prices were low, ranging around $6.50 per unit for 60 per cent WO_3 concentrate. The outbreak of the war first paralyzed and later stimulated the market until toward the close of the year the price rose to $9 per unit, which was a highly profitable figure.

It was not until late in 1915 and early in 1916, however, that the boom prices became manifest. In Boulder County they rose rapidly to as high as $90

per unit, though a story of mine promotion and stock jobbing is said to have been connected with that fancy price. At all events, $75 per unit was realized for large quantities of concentrate and producers became so optimistic as to have visions of a $100 market. About two months ago one small producer actually refused $82.50 per unit, holding for $100; just lately he sold for $20 and was glad to get it.

It is reasonable to assume that the possibilities of production from obscure sources were not appreciated in the larger districts of Boulder and Atolia; but the fact remains that from sporadic occurrences of tungsten ore in South Dakota, Utah, Arizona, New Mexico, Idaho, and parts of Colorado other than Boulder County, a considerable output was forthcoming. Imports also grew, shipments from South America and Japan swelling the domestic supply. The foreign product, moreover, was in some cases higher in grade than our own, and proportionately more desirable. The inevitable result was a satiated market.

The situation at the present writing is about this: With the exception of a few large producers who have their own eastern connections, independent operators are unable to market concentrates. Buyers say that there is a plentiful supply in the East, and while there is still a nominal market in the West, the producers have completely lost control of it. From $75 per unit the nominal market has slumped rapidly to $50, $40, $30 and even $25 without arousing any eagerness to buy. A still further drop is anticipated among buyers until the level is reached at which imports will be unprofitable, especially under the ocean freight rates now prevailing. They look for a base price of perhaps $12 to $15 per unit, and think the market may be stabilized at that figure. But even such a market, if open and steady, would be a boon to the tungsten industry. As for the future of producers, it will be a case of the fittest surviving. Good mines served by modern concentrators will stay longest in the field; the adventitious operator with poor equipment must retire.

Production of War Steel

Statistics of the production of finished steel in the United Kingdom in 1915, just made public, suggest that the production of shell steel in England has not been as large as usually surmised, and our own production of this material, whether exported in finished or unfinished form, becomes relatively more important.

Unfortunately the British statistics lack precise details on this point. There is one item, "General merchant steel (not included under angles and girders, etc.)," given at 534,503 gross tons, while the general item of unenumerated products is given at 770,981 tons. Rolled steel rounds must be included in the one category or the other and thus cannot have amounted to a large tonnage, particularly when it is observed that the exports of "steel bars, etc." in 1915 amounted to 489,464 tons, of which 349,297 tons was for France, that for France being undoubtedly shell steel almost exclusively. Production of steel forgings, in the rough, is given at 118,102 tons. Apparently, therefore, the production of steel for British conversion into shells can have amounted to only a few hundred thousand tons.

Exports of steel bars from the United States in 1915 amounted to 403,577 tons, the great bulk of this material being destined for conversion into shells in French machine shops. Thus it would appear that France has been producing the preponderating quantity of shells, drawing shell steel from both England and the United States, and presumably having a fair steel production of her own.

There are no data available whereby the steel consumed in shell manufacture in the United States can be estimated. The value of finished but not loaded shells exported in 1915 was about $50,000,000, while the value of loaded shells exported seems to have exceeded $75,000,000. When the statistics of steel bar production in the United States become available it may be possible to make an estimate of the tonnage, by observing the extent to which the proportion of steel bars produced is above normal.

It is quite erroneous to assume, therefore, that the British steel industry is engaged very largely in the manufacture of ammunition, and that orders coming to this country simply represent small additional requirements. The British steel industry, however, is as busy as it can be when it suffers more or less from a shortage in labor. While the production of steel rounds, as indicated, has been rather small, measured only by hundreds of thousands of tons, the total production of finished rolled steel, including pipes and tubes, etc., amounted in 1915 to 6,325,844 tons. That compares with a production of 8,350,944 tons of steel ingots and 8,793,659 tons of pig iron. The ingot and finished steel figures agree well, showing a loss in weight of 23 per cent from ingot to merchantable production, while American statistics have for years run at about 24 per cent. The relation between steel and pig iron, however, is quite unusual, for the steel ingot production was easily the largest on record, whereas the pig iron production fell far short of that in many previous years. In 1913 there were produced 10,481,917 tons of pig iron and 7,663,867 tons of steel ingots, against 8,793,659 tons pig and 8,350,944 tons steel. Thus the excess of pig iron over steel ingots was reduced from 2,818,050 tons to 442,715 tons, while the proportion of steel to pig iron rose from 73.1 per cent to 95.0 per cent. A part of the decrease in pig iron is to be accounted for by a decrease in exports from 1,124,181 tons to 611,617 tons and a small part to a reduction in stocks, while the remainder is to be attributed to a reduction in the production of iron castings.

If the British production of shell steel was smaller than might have been assumed, the production of ship steel was enormous, as suggested by the following statistics of production:

Gross tons—1915	
Plates, ⅛ in. and thicker	1,367,577
Angles, tees, channels and sections	762,717
Girders, joists and beams	343,617
Total	2,473,911

As the exports of such material were only 205,163 tons (against 254,947 tons in 1913) and as there can certainly have been no large use of plates and structural material for ordinary purposes it is quite evident that the great bulk of the material indicated above, probably almost 2,000,000 tons, was for the construction of ships.

Thus it is seen that in the case of England the demand for steel created by the war is much larger for building ships than for making shells. The export demand upon the United States has reflected heavy requirements in steel other than for making shells, conspicuous lines being rails, railway rolling stock and automobiles, particularly what are commonly called "trucks." They appear in the official export statistics as "commercial automobiles," a designation that has somewhat run amuck, by the way, considering the use to which they are put.

Madison, Wisconsin

It is purely a coincidence, but a happy coincidence, that three articles in this issue have emanated from Madison, Wis. Dr. Oliver P. Watts of the University of Wisconsin describes an elaborate electric arc furnace designed for laboratory use on page 681. Mr. Oliver W. Storey of the C. F. Burgess Laboratories deals with the theory and practice of the sherardizing process on page 683. Mr. Henry E. Surface of the Forest Products Laboratory discusses the use of wood waste as pulpwood on page 701. Here we have three distinct Madison centers of research represented—a state institution, a private institution, and a federal institution respectively—independent of each other and each with its own sphere of influence, yet correlated and thereby indicating in a pretty manner the catching character of the research spirit. In these days when the national organization of research and the creation of new nuclei of research in the United States has become an urgent matter, it is pleasant to be reminded of how much has already been accomplished. And when those American cities are counted, in which a true spirit of research has been liveliest and most active at an early date, Madison, Wis., is among those in the front rank.

Physical Chemistry of Assaying and Cupellation

From a technical standpoint, any industrial chemical or metallurgical process is in the end applied physical chemistry. We don't mean that physical chemistry is all that is required. Mr. Maximilian Toch is probably quite right in saying that "chemical engineering is 49 per cent chemistry and 51 per cent business acumen." What we mean is that his 49 per cent chemistry must be applied physical chemistry—not pure chemistry. Nor do we want to raise the question as to what is more important in applied physical chemistry—the foundation supplied by the physical chemist or the superstructure raised on it by the engineer. Our claim is that to produce industrially sound results, a combination between engineer and physical chemist, not engineer and pure chemist, is needed.

The development of the flotation process brings out this very point very clearly, as we tried to show in recent comments on the theory of flotation. But the flotation process is still considered by too many people as something of such an exceptional nature that it might require quite naturally exceptional measures. It is therefore pleasant to call attention to the article by Prof. Boyd Dudley, the first part of which appeared in our issue of June 1, while the concluding part is published in our present issue, as in this article it is clearly shown that a study of equilibrium conditions, according to well-known principles of physical chemistry, is required to understand the silver losses in such a simple every-day procedure as the fire assay of gold and silver ores by the crucible method. Indeed, the same fundamental principles of distribution equilibrium which Professor Dudley applies to the silver loss in the fire assay of gold and silver ores, apply to the slag loss of copper in matte smelting and the slag losses of lead and silver in lead smelting. The subject is therefore of decidedly more than theoretical interest.

In the fire assay of gold and silver ores equilibrium conditions are established in the crucible fusion. Professor Dudley's experimental results prove conclusively that at constant temperature a definite distribution of silver between lead and slag will occur, the silver passing either from the slag to the lead or from the lead to the slag as may be necessary to establish equilibrium. It is also shown that as the silver concentration in the lead increases, its concentration in the slag required to produce equilibrium will increase in direct ratio. That is, the ratio of the equilibrium concentrations of silver in metallic lead and in a slag of given composition is a constant at constant temperature. But the temperature has an enormous effect—an increase of temperature produces quite an increase in the solubility of silver in the slag.

In the second part of his paper, published elsewhere in this issue, Professor Dudley in discussing the effect of litharge shows that at constant temperature the ability of slags to dissolve and retain silver is mainly dependent upon the molecular concentration of the litharge and is independent of the so-called silicate degree or oxygen ratio of the slag. The slags may be regarded as simple solutions of the various oxides, and litharge is the only one having any appreciable dissolving power for silver.

The results are important in cupellation just as in assaying if we interpret the results as applying to pure litharge, and while the author states that much more experimental work is necessary before the physical chemistry of cupellation can be thoroughly understood, it is pointed out that further experiments should be made with pure litharge. The principal difficulty is in securing a proper container. Another field for further study is in regard to the condition or state in which silver is held in solution by litharge. The attack of the foregoing problems from the standpoint of physical chemistry has been very productive, and when further extended, the results should have an important bearing on the control of assaying and cupellation.

Readers' Views and Comments

Chemistry and the Daily Papers

To the Editor of Metallurgical & Chemical Engineering

Sir:—There seems no escape from Dr. Hesse's conclusion that the first point of entry for technical publicity must be by way of the editors of our dailies. But Dr. Hesse will probably have his work cut out to "educate our editors as to what the country should know." The unfortunate experiences which Dr. Hesse describes indicate this clearly; though this is not precisely the conclusion he draws from them nor does the real significance of the crowding-out of the results of his collaboration with "an efficient editorial writer" because the space was needed for something else seem to occur to him.

It is tremendously difficult to put a technical story into popular form in a way which will make it attractive and acceptable to the average person—and the average editor. *Hinc illæ lachrymæ.* It is not going to be done to any large extent by the newspaper man, if for no other reason than his lack of knowledge of the subjects to be dealt with. Perhaps it is also not going to be done to any large extent by the technical man since it is rare to find a technical man who can write attractively, still rarer to find one who can write for the standpoint of a layman, and he usually has enough to keep him otherwise busy. But it can be done, and if the chemist wants publicity he has got to do it. Unless he does it is of little use to complain of the consignment of his contributions to the waste-paper basket or of their being crowded out on account of lack of space.

F. AUSTIN LIDBURY.

Niagara Falls, N. Y.

Liquid Jets for Absorbing Gases in Liquids and the Flotation Process

To the Editor of Metallurgical & Chemical Engineering

SIR:—I have read with great interest in your issue of March 1 last an article designated "Universal Flotation Theory," by C. Terry Durell and beg that you will publish the following notes:

Mr. Durell is not the first man by any means to use the liquid jet as a means of absorbing either air or other gases into water.

In the year 1908 I erected an electrolytic chlorine generating plant for the Mount Morgan Gold Mining Co. of Queensland and by means of an acid-proof ejector using water under pressure instead of steam, I successfully absorbed 300 lb. of chlorine gas per twenty-four hours in 24,000 gal. of water. The chlorine water was used for leaching gold ores.

This ejector, which I could place in my pocket, replaced a 50 ft. tower and worked without interruption night and day for twelve months. Several years ago I tried to get the ejector tried in a flotation plant on two different mines at Broken Hill, being convinced that both its first installation cost as well as its running cost would be less than that of any other method. However, I could get no one to listen to me.

I am at present erecting a copper leaching plant for oxidized ores in which I intend to absorb sulphur dioxide gas into my solutions by means of ejectors.

In a recent paper entitled "The Electrolysis of Copper Sulphate Liquors Using Carbon Anodes," read by Mr. Lawrence Addicks before the American Electrochemical Society the author points out that it is impossible to obtain complete absorption in solution, of sulphur dioxide gas, derived from roaster fumes unless it be put under pressure. He has used a 50-ft. vertical pipe full of solution for this purpose, the gas being delivered at the bottom of the pipe by means of an air compressor.

An ejector, properly used, will absorb all the gas which it can pull with a given stream of solution, as the gas is subjected to pressure while passing through it and is forced into intimate contact with the jet.

If a small centrifugal pump and an ejector be placed in a closed circuit the circulating solution may very quickly be supersaturated with any gas.

I hope that Mr. Durell may have every success with his patent in America, but would warn him that his idea is not patentable in this country, as I placed it in commercial operation here about eight years ago.

B. DU FAUR.

Burra Copper Mine, Kooringa, South Australia.

Flotation and Cyanidation

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of May 15 you propose the following questions:

1. Are oil-flotation products—concentrates and tailings—as readily cyanided as similar products from ordinary wet concentration?
2. To what are the difficulties, if any, to be ascribed, and what are the remedies?
3. Are the difficulties likely to prove serious enough to react against cyanidation and restrict its use?
4. Is it possible that a combination of flotation plus smelting may in some cases prove more economical than cyanidation?
5. Does flotation appear to-day in any sense a competitor of cyanidation in the treatment of gold and silver ores, or will it prove a valuable accessory process?

The answers to questions 1, 2 and 3 can now be little more than suggestive, since the few plants practicing flotation upon gold and silver ores have not up to the present time, so far as I am aware, attempted cyanidation of any of their products upon a mill scale, and furthermore, published accounts of comprehensive scientific investigations covering these points have not appeared. The few results of empirical experiments so far published, as might be expected, have been contradictory, and therefore no definite generalizations can be made upon the basis of them. Most operators are in a hurry to derive the benefits from flotation at as early a date as possible, therefore—*rightly*—they have confined experimentation to empirical tests which would prove or disprove the suitability of their ores to flotation, and which would establish the factors for their particular cases which would result in the best economic result.

It appears that the tailing from flotation is, in the majority of cases, amenable to cyanidation; that is, provided that the original ore contained nothing to interfere. Regarding the cyanidation of the concentrate, there is a great variety of opinion. One well known metallurgist has published the results of tests made upon a flotation concentrate from a gold ore which leaves little to be desired as regards cyanidation, while another equally well known metallurgist has published results of tests which indicate that the flotation concentrate from another gold ore is not amenable to cyanidation.

This leads to the conclusion that the difficulty does

not always exist. In cases where it does exist, it may be due to the difference in the character of the ores treated, or to the difference in the behavior of the oil or oils used. The interference may be due to either physical or chemical causes such, for example, as a film of oil coating the mineral, or actual combination of certain constituents of the mineral with the oils used. This latter suggests itself on account of the well known fact that certain oils attack some of the metals. However, this is purely speculative since it has in no particular case been definitely proven.

The remedies suggested have been saponification of the supposed oil film by preliminary treatment with a caustic alkali, washing with a light mineral oil, such as gasoline, which is presumed to act as a solvent for the oil film, and various other expedients which have been tried more or less at random. The efficacy of these remedies in cases where real difficulty exists has not been clearly demonstrated. Where fuel is cheap and roasting can be done economically, a thorough oxidizing roast will with but very few exceptions solve the problem in the case of concentrate containing gold with little or no silver; but as I have elsewhere pointed out on a number of occasions, silver minerals are rendered refractory to cyanidation by an oxidizing roast. A chloridizing roast in such cases may be at times effective, but is not generally looked upon with favor by metallurgists, on account of the possibility of loss of the precious metals. The fear sometimes expressed that the oil may be carbonized during roasting and thereby cause premature precipitation is not well founded since with proper roasting it would be entirely consumed.

In my opinion, the difficulties even in the case of silver concentrate are not always insurmountable, but nevertheless there are doubtless cases where cyanidation could not be used.

There is no question but that a combination of flotation plus smelting will in some cases prove more economical than cyanidation. Here much depends upon the smelting rates and cost of transportation. A good example of a case where this works out advantageously is the practice at Cripple Creek, where flotation plants with shipment of concentrate are being introduced rather than expansion of existent cyanide plants. In fact, certain of the cyanide plants are being remodeled into flotation plants. It might be added that Cripple Creek is not by any means the only district where flotation is proving more economical than cyanidation, for a number of such cases have been brought to my attention.

It seems to be the opinion among thoughtful metallurgists who have not been completely carried away by the wave of enthusiasm which has swept the world for flotation that flotation will not to any considerable extent displace the cyanide process in the treatment of gold and silver ores, but as previously pointed out, it will in certain cases, perhaps a good many, prove more economical and it will in many other cases prove a valuable accessory treatment to cyanidation. The reason that flotation will not displace the cyanide process is that most companies prefer to produce bullion. Furthermore, many gold and silver mines are located far from smelting centers, which means high freight rates and renders the shipment of concentrate out of the question.

There is, however, one possibility which tends to render such a prediction uncertain, and that is the possibility of obtaining an extremely high-grade concentrate such as could be directly melted with simple furnace equipment in much the same manner as cyanide precipitate. If we can conceive of this ever being accomplished, and it is not impossible, then cyanidation will certainly have a most formidable rival in flotation.

G. HOWELL CLEVENGER.

Palo Alto, California.

Flotation and Cyanidation

To the Editor of Metallurgical & Chemical Engineering

SIR:—In the effort to extract gold and silver, by cyanide, from the concentrate obtained in flotation, experience is bringing out varied results. Much is being said in despair of operating the two processes conjointly. The usual flotation process depends upon the presence of oil in a mixture containing the ore which is agitated to produce the concentration. The cyanide process, in turn, is operative only by means of freely circulating aqueous solutions, which produce chemical reactions that are among the most intricate and delicate in all chemistry. For the proper action of these solutions, it is necessary that the dissolved cyanide enter into every minute passage of every porous grain to diffuse and to do its chemical work upon the metal. The oil of flotation thus becomes a harmful impediment in cyanide extraction. The flotation, which is desired to precede the cyanide extraction, furnishes a concentrate which practically consists of particles that have been oiled, or are oily. Though the extent of this oiling is in some measure adaptable to altered needs, and though the amount of the oil is, in all cases, extremely small, yet the effect is pronounced.

Were it not for the proverbial irreconcilableness of the oil and the water, the treatment of ore by a combined process of flotation and cyanidation would promise great economy. Cyanide treatment, in many cases would be a direct process for recovering the valued metal of the concentrate, without the costs involved in shipment and in smelting. A low extraction by the cyanide, however, is the usual result.

The interference to the extraction of gold or silver from the flotation concentrate is a result of physical action of the oil, and in addition to this, usually, also to certain chemical reactions by which cyanide is destroyed and the extraction retarded or prevented. There are, of course, many different kinds and qualities of flotation concentrate. The varied minerals and the variety of oils give rise to as many qualities of concentrate as there are places of operation. The substance which we regard as oil is not set apart by any determining chemical composition, nor definite nature. It ranges from liquid which is oily beyond all question to that which in reality is scarcely more than an alcohol, ether, or in some cases, an organic solution of a dissolved gum or resinous substance. Some of the so-called oils have little of the quality which we understand as characteristic of oil. Thus by including among the oils all those substances that have only some single semblance to oil, it is natural that the action of "oil" upon ores is varied. Among those oils which, by their numerous characteristic oily qualities, give no ground for uncertainty, there is varied susceptibility to saponifying and oxidizing agents and to solvents. Discrimination is the beginning of an effort to reconcile cyanidation with flotation.

The physical interference of certain oils in rendering cyanide solutions incapable of attacking the gold or silver of the grains of ore has been proven repeatedly by experiment and trial. The entire physical behavior of the concentrate is altered by the presence of the oil. The alteration was a necessity to produce the action that was sought for the flotation. While it is possible to obtain a flotation concentrate without the use of oil, this is commonly not practicable. Oil can be saponified and thus dissolved or washed away from any material in the form of a soap, or, when present in appreciable

amount, it can be removed nearly completely by simple oil solvents. Certain oils, moreover, are capable of oxidation and elimination through varied chemical reactions. Long treatment and agitation, without removing the oil, can be made to partly counteract the resistance offered by the oil. In the laboratory many such possibilities destroying or removing the oil seem indicated.

In the commercial treatment of ores, on the other hand, these delicate and erratic actions become sources of possible irregularities and are liable to influence from impurities. Roasting a concentrate is, of course, always a means of destroying or expelling an oil, but in some cases roasting is a hindrance to cyanidation and in all cases the operation seriously adds to the cost of treatment.

The greater number of oils allowed to remain in the flotation concentrate are not chemically without action upon cyanide solutions. Most oils have chemical qualities which also interfere by the absorption of oxygen. The animal and vegetable oils are generally oxygen-consuming. Combining with the oxygen at a critical time and place, when gold starts to combine with the cyanide and when the oxygen is needed, the extraction fails. Reduction and side reactions result in an attack upon the cyanide solvent. Particular interference is liable in the presence of the sulphide minerals soluble in alkali. Compounds, as well, between mineral bases and oily acids, produce physical effects that retard the dissolving action.

On the whole it is seen that ores must be judged for the application of definite oils, and that the oils must be chosen not alone for the merits which they show in flotation, but for the influences upon the cyanide extraction.

The mineral oils, for the most part, are among the most inert of all organic substances. These oils suffer little or no alteration through any treatment, and their harmful effect upon cyanidation is physical. The drying oils have found little favor in flotation. Between these two extremes in oils, with the quality of inertness on the one hand and readiness to oxidize, saponify or react, on the other, there are all gradations including oils of vegetable origin and extending through those produced by destructive distillation to those which are the natural petroleum products. Numerous oils are capable of offering both the physical and the chemical interference, and would always be avoided. Others introduce but a single interfering influence for which there would possibly be found a corrective.

Before flotation combined with cyanidation can be pronounced to be a general possibility with chosen oil, investigation must be made more extensive than even yet has been done. Study must be made of the properties of the many kinds of oils which are capable of employment in flotation. Many of these are imperfectly understood.

The effect which the oil has upon the surface tension of the liquid, its affinity for the different minerals, and the flocculating or thickening effect upon a froth or concentrate demands consideration along with the oxygen-consuming power, saponification in the alkaline solution, and the action upon the cyanide solvent.

In the choice of an oil the important requirements of flotation must be made subordinate to the demands of the cyanide treatment. There appears to be nothing permanently fatal, with further understanding, to a combination of the two processes of flotation and cyanidation, but there will be required a modification of present practice and a more discriminating understanding of the materials used.

ERNEST A. HERSAM.

Berkeley, Cal.

The Iron and Steel Market

The steel market has grown still more dull, and market conditions in the next two or three months are likely to approximate the summer conditions of a dull rather than of an active year. The condition is that of the market having been sold and bought to a standstill in the past few months, with prices now so high that new enterprise is discouraged. Railroad buying has practically ceased, and there is no business being done in fabricated steel representing regular investment, though there is a fair tonnage representing works extensions. Manufacturing consumers generally are well covered with material and in the retrospect it is more plainly evident that their importuning mills for better deliveries, as they have been doing for months, represented a psychological rather than a physical condition, a fear that they would not secure adequate deliveries in future rather than a condition of their actually needing more steel at the moment. In very few instances, it would appear, have manufacturing consumers received less steel than they really needed.

Exports

Iron and steel exports in April amounted to 385,000 gross tons, against 438,058 tons in March, April being the record month for exports, barring March and last August. Exports in the first four months of this year were at the rate of 4,600,000 tons per annum. The value of all iron and steel exports made a new record in April, at $58,722,411, this value including that of machinery, hardware, cutlery, etc., as well as of the commodities reported by weight. The total value for four months of the calendar year is $222,821,901. Besides these exports returned as iron and steel there is iron and steel involved in exports of agricultural implements, motor cars, railway cars, loaded shells, etc. Unloaded shells and locomotives are included as iron and steel.

Export demand has been particularly heavy the past two or three weeks, and there is large inquiry now pending. The shell steel for the balance of the year appears to have been practically all bought, sales since May 1 easily totaling more than half a million tons, while there remains large inquiry for barb wire for war purposes, Russian inquiries alone being estimated at more than 100,000 tons. What is perhaps more significant is that there is much heavy demand for steel products from neutral countries. To date our exports to neutral countries have been light, much smaller than in 1912 and 1913, hitherto the best export years.

Pig Iron and Steel

A rate of pig iron production of 40,000,000 tons per annum was approached within 2 per cent last February, but the full rate has not yet been attained, and 40,000,000 tons may prove to be the asymptote, at least until summer is over. For three months or more a common market opinion has been that with few blast furnaces being built and many extensions being effected to steel making capacity the time would arrive when there would not be enough pig iron, and then, as pig iron had advanced only about 45 per cent while steel, finished and unfinished, had doubled in price, pig iron would "go up." It does not do so, however, but on the contrary has turned a trifle weak in the past fortnight. Southern iron actually declining, and this is significant since almost invariably Southern iron leads the general pig iron market in both advances and declines. The theory that the unusually wide gap between pig iron and steel was destined to be bridged may prove correct eventually by steel declining instead of pig iron advancing. The market is very dull in all districts, and more foundries than formerly are requesting that shipments

be held back. We quote: No. 2 foundry iron, delivered Philadelphia, $20.25 to $20.75; f.o.b. furnace, Buffalo, $18.50 to $19; delivered, Cleveland, $19.30; f.o.b. furnace, Chicago, $19; f.o.b. Birmingham, $14.75 to $15; f. o. b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $21; basic, $18.25; foundry, $18.50; malleable, $18.25 to $18.50; forge, $18. Ferromanganese has grown very dull and can be bought at $250 for prompt shipment, against $400 obtained a few weeks ago. The contract market is unchanged at $175.

Steel

The soft steel market has become still easier. Recently enough offerings of odd lots developed for prompt shipment to move the market from $45 down to about $40 to $42, though even $40 was shaded. For a time the large mills held forward deliveries at the $45 level, but it is now evident that round tonnages for forward delivery could be bought at $40 to $42, either billets or sheet bars. There is very little inquiry, and the market is rather flooded with prompt lots, chiefly second discards and rejected steel, made against war steel orders.

Finished Steel

Regular mill prices, for forward delivery, are unchanged. Bars and shapes are 2.50c. and plates 2.90c. Premiums for prompt shipment show a declining tendency. Galvanized sheets are down from 5c. to 4.75c. on account of the decline in spelter.

The Non-Ferrous Metal Market

Saturday, June 10.—The last two weeks have been very dull for most of the metals. Copper has held firm despite this dullness, while tin declined gradually until the last two or three days when it showed signs of an upward turn. The same is true of spelter. Lead was lowered ½ cent by the Trust and the market still continues dull.

Copper.—The enormous production and small exports, combined with the overbought domestic market have contributed to make a dull market. Offers seem to be plentiful, but prices are at about the same level of 28.50 for prompt electrolytic. The markets abroad have also been dull. Exports for May were 14,622 long tons. Prices for future delivery are but very little lower than spot prices. Electrolytic for July and August is 28.25 and for September and October is 28.00.

Tin.—Up until a few days ago the tin market has been reacting both here and abroad. About the 7th of the month the market became more firm and developed an upward tendency. Spot Straits tin dropped from 47.00 on May 29 to 44.25 on June 6. To-day it is quoted at 44.50. The home consumption is good and arrivals for May were 3912 tons.

Lead.—On June 5 the Trust lowered its price to 7.00 cents. Independents are cutting this price and offerings are to be had at 6.90 and under. The market has been dull.

Spelter.—As in the case of tin, spelter was weak up until about June 5, when consumers began to take more interest in the market and a slight advance from 13.30 to 13.55 was made. Since then the market has continued firm, with a fairly good demand. Prompt spelter is quoted at 13.55-13.80.

Other Metals.—Antimony continues dull and has dropped to 22 cents, a decline of about 4 cents in the last two weeks. Aluminium is still quoted at 60 cents and platinum at $78 per ounce. Quicksilver continues to drop and is now at $70 per flask. Silver is quoted at 66⅝.

Concerning the recent slump in tungsten we comment on our editorial pages. As is shown there, it was an inevitable event.

New Revenue Measure Likely to Include Dyestuffs Tariff

The House of Representatives Ways and Means Committee is framing a new national revenue measure which is expected to include increased duties on dyestuffs, following closely the recommendations of the Hill bill. (An account of hearings on the Hill bill was given in our issue of Feb. 1, 1916, p. 125.)

In addition to providing for increased duties it is expected that provision will be made to limit the time, which the duties will remain in effect, and also that anti-dumping legislation will be included in the interests of fair trade. The committee has been considering the bill, which is concerned with general sources of revenue such as the income, inheritance and other taxes, for about two weeks and it should be reported out of the committee in a short time. Every effort is being made by the Democratic members of the committee to frame the bill so that it will meet with as little opposition as possible, and hopes are entertained that it may be passed by both Houses by July 1, or soon thereafter. The uncertainty connected with legislation must, however, be given due consideration.

Annual Meeting of Iron and Steel Institute in London

The annual spring meeting of the Iron and Steel Institute was held in London, May 4 and 5, at the Institution of Civil Engineers. The retiring president, Mr. Arthur Cooper, occupied the chair at the opening. An abstract of the annual report was read by the secretary, Mr. G. C. Lloyd. The number of new members elected fell considerably below preceding years, while financial statement compared favorably with other years. The new president, Sir William Beardmore, was inducted into office. He has been treasurer since 1912, and is chairman and managing director of William Beardmore & Co., Ltd.

The new president upon taking the chair presented the Bessemer Gold Medal to F. W. Harbord.

The new president in his address on science in factories emphasized the necessity of looking upon science as the dominant factor in industrial and economic considerations. There must be co-operation between laboratory research and manufacturing development. He also laid great stress on the attitude of workers, and said that their failure to utilize to the best advantage improved methods of manufacture evolved by experimental research discourages industrialists in their evolution and application. When a charge of lack of enterprise is made against manufacturers, blame should at the same time be laid at the door of the workers, who do not realize that their interests are intimately affected by the attitude they display in such cases. He thinks that research should be a charge on the selling price, and that it is essential that the volume of output should be increased. He is also in favor of a high rate of wage and large total earnings per worker per week. This is attainable without forfeiture of a satisfactory profit, provided all workers make the most of all the appliances which scientific research and mechanical experiment may place in their hands.

The awakening of the workers is as important as the furthering of scientific methods. Thus while we foster metallurgical science we must not neglect the equally important subject of industrial economics and the duty of the state and the worker towards such problems.

At the second day's meeting a discussion took place as to the position of the Institute in regard to trade

prospects after the war. The grants under the Carnegie Research Scholarship Fund were announced by the secretary.

Meeting of New York Section of American Chemical Society

The last meeting of the season of the New York Section of the American Chemical Society was held in Rumford Hall, Chemists' Club, Friday evening, June 9. The chairman, Dr. T. B. Wagner, presided, and the meeting was well attended. Upon recommendation of the committee, a resolution was adopted approving two bills introduced in the Legislature. These are the Johnson bill, to require the use of the Centigrade scale in all Government publications after 1920, and the Newlands bill, to establish industrial research stations in each State. (Two very interesting articles on the Newlands bill by Dr. W. R. Whitney were given in our issues of May 15 and June 1). Dr. George F. Kunz gave a short talk advocating the "more daylight" plan of moving the clock ahead as initiated by Germany and adopted by other countries.

The committee report on "University and Industry," presenting its findings, conclusions and recommendation, was read by Dr. Charles Baskerville, chairman of the committee. The committee advocates the appointment of a permanent committee, representing both universities and industries, such committee to study opportunities and make recommendations for cooperation.

A paper was presented by Dr. George A. Burrell of the Bureau of Mines, Pittsburgh, Pa., on vapor pressures and gas analysis by liquefaction and fractional distillation, and the extraction of gasoline from so-called "dry" natural gas by absorption methods. The paper was illustrated by numerous lantern slides, showing the apparatus used and results obtained in determining the vapor pressure of twelve gases at temperatures as low as — 170 deg. C. Experiments were also described on the deviation of gases from Boyles law at higher pressure, and it was explained that as the natural gases were more compressible at higher pressures than would be calculated from Boyles law, measurements of natural gas would have to be revised. Accurate gas analysis was developed by the liquefaction and fractional distillation method. Dr. Burrell explained recent developments in the extraction of gasoline from natural gas by absorption, a full account of which was given in our issue of June 1, page 651.

A paper was presented by Dr. Frederick E. Wright of the Geophysical Laboratory, Washington D. C., on the use of the petrographic microscope in analysis. The petrographic microscope is a valuable adjunct in chemical analysis, and Dr. Wright explained several important uses to which it has been put in the identification of solid materials. It is especially helpful in identifying mixtures of several different solids, the chemical analysis of which would require a long time. With the microscope the work can be done very quickly. Some interesting experiments were shown on the screen by a microscopic projection lantern. A few organic salts were melted, placed in front of the lens and then allowed to crystallize. The growth of the crystals could be seen very plainly, and the different characteristics of the different substances were apparent. These crystals appeared in colors as interference screens were used.

The Maryland Silicite Co., 609 Munsey Building, Baltimore, Md., is opening up a deposit of infusorial earth on the Patuxump River, Md.

Estimated Cost of Making Gasoline by the Rittman Process

The Bureau of Mines has issued the following estimates showing the cost of making gasoline by the Rittman process. These estimates are based on a five-tube plant and the results of a five-day run, with a recovery of gasoline of 17 per cent and with varying prices of fuel oil. (Fuel oil is oil from which gasoline has already been extracted by the ordinary process of refining.)

The capacity of a single tube was 1.55 bbls. per hour or 37.2 bbls. for 24 hr. With loss, 10 per cent, would yield 17 per cent gasoline, the balance being fuel oil, as valuable as original fuel oil.

The estimated cost of a five-tube plant	$15,000.00
Estimated cost of building to house plant	5,000.00
Total	$20,000.00

Monthly capacity, 5580 bbls. Deducting about 10 per cent for "shut downs" leaves net capacity 5000 bbls. Yield of gasoline 17 per cent, 850 bbls., or 35,700 gals. Loss, 10 per cent, equals 550 bbls. Residuum, 73 per cent, equals 3650 bbls.

Cost of Fuel Oil $0.50 per Bbl.

Expense.	
5000 bbl. fuel oil at $0.50 per bbl.	$2,500.00
Labor for one month	560.00
Fuel (1050 M ft. at 15c.)	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each	200.00
Refining cost 20c. per bbl.	1,000.00
	$4,620.00
Credit.	
3650 bbl. residuum at 50c. (fuel oil)	1,825.00
Net Cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline	$2,795.00
Cost of gasoline per gal. 7.8c.	

Cost of Fuel Oil $1.00 per Bbl.

Expense.	
5000 bbl. oil at $1.00	$5,000.00
Labor	560.00
Fuel	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each	200.00
Refining cost	1,000.00
Total cost	$7,120.00
Credit.	
3650 bbl. residuum at $1.00 (fuel oil)	3,650.00
Net Cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline	$3,470.00
Cost of gasoline per gal. 9.74c.	

Cost of Fuel Oil $1.47 per Bbl.

Expense.	
5000 bbl. oil at $1.47	$7,350.00
Labor	560.00
Fuel	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each	200.00
Refining cost	1,000.00
Total cost	$9,470.00
Credit.	
3650 bbl. residuum at $1.47 (fuel oil)	5,365.00
Net cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline	$4,105.00
Cost of gasoline per gal. 11.5c.	

Cost of Fuel Oil $2.10 per Bbl.

Expense.	
5000 bbl. oil at $2.10	$10,500.00
Labor	560.00
Fuel	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each	200.00
Refining cost	1,000.00
Total cost	$12,620.00
Credit.	
3650 bbl. residuum at $2.10 (fuel oil)	7,665.00
Net Cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline	$4,955.00
Cost of gasoline per gal. 13.9c.	

The Dolomite Products Company of Cleveland, Ohio, is erecting at Maple Grove, Ohio, a 450 x 85 ft. building for the manufacture of magnesite. The plant will be thoroughly modern and the processes entirely automatic. The plans have been worked out by the Schaeffer Engineering and Equipment Company of Tiffin, Ohio.

Faraday Society Meeting

The seventy-ninth ordinary meeting of the Faraday Society was held in London on May 9, 1916, with **Sir Robert Hadfield**, president, in the chair.

Theory of Gels

Mr. **Emil Hatschek** presented a paper on "an analysis of the theory of gels as systems of two liquid phases."

The generally accepted theory of the constitution of gels is that they are systems of two liquid phases. No attempts have been made to determine whether this assumption accounts for various observed properties of gels. The present paper is a mathematical investigation directed to determining whether the observed elastic properties of gels are compatible with their being composed of two liquid phases only. If this is the case, it follows that their elasticity must be due exclusively to the interfacial tension between the phases, viz., the work done in stretching a cylinder of gel must be equal to the surface energy developed. It follows immediately that the function connecting stress and elongation must be the first differential of that connecting surface and elongation. To obtain the latter, various structures, consisting of space-filling polyhedra such as rhombohedra, rhombic dodecahedra and cubes are examined and the increase in surface calculated for deformation in the direction of principal axes. The curves obtained by plotting surface as ordinates against elongation as abscissæ are similar in all cases and obviously represent the same function, although analytical treatment is only carried out for one case. Since the curves all show an inflexion, it follows that the stress reaches a maximum at the elongation at which the inflexion occurs and then decreases, *i.e.*, to stretch the gel beyond this point a smaller stress would be required than for a smaller elongation. This, as well as the shape of stress-elongation curves obtained experimentally, which differ very considerably from the theoretical curve, shows that the assumption of two liquid phases is inconsistent at any rate with the elastic behavior of gels.

Prof. Alfred W. Porter, F.R.S., pointed out that Mr. Hatschek's criticism did not distinguish between an ordinary liquid and one as viscous, say, as cobbler's wax, which acted as a solid to forces applied rapidly. He thought, too, that in the case of two liquid phases the straight-sided forms assumed would not persist in equilibrium; the continuous would shrink away from the disperse phase and form gaps, unless the former were exceedingly viscous. Mr. Hatschek's argument was sound if polyhedra were formed.

Dr. C. H. Desch thought the geometrical forms of the structure would be neither rhombohedron nor rhombic dodecahedron, but Kelvin's fourteen-sided polyhedron with curved faces.

Mr. Hatschek, in his reply, added that he conceived gels as of an ultimate crystalline structure, with the crystals thinned and filled with liquid.

Solid Solutions of Metals and Intermetallic Compounds

In introducing two papers by Mr. **F. C. Thompson**, the president expressed his appreciation of the encouragement the University of Sheffield gave to young metallurgists like Mr. Thompson in the prosecution of research, and he remarked on the value of the author's work. As an incentive to him he offered a prize of £50 to continue his researches and present the results to the Faraday Society.

The first of Mr. Thompson's papers dealt with "the properties of solid solutions of metals and of intermetallic compounds."

By considering the space lattice of a solid solution of two metals as resulting from the substitution of atoms of B for an equal number of A in the space lattice of the latter, it is possible to predict with some completeness the properties, hardness, specific volume, electrical resistance of the alloy.

The distortion of the space lattice resulting from this substitution of other atoms of different atomic volume explains the generally marked resemblance of the properties of solid solutions of metals to those of a metal which has been mechanically deformed. An elementary mathematical treatment results in a parabolic curve, which corresponds with that practically observed, for the relationship of hardness to concentration in a series of alloys, such as those of gold and silver which form an uninterrupted series of solid solutions.

The influence of the atomic volume on the readiness with which solid solutions are formed, and the properties of intermetallic compounds are also briefly considered.

Dr. C. H. Desch suggested that an examination of solid solutions such as that of gold and silver by means of Bragg's X-ray spectrometer might throw light on the structure of the space lattice.

Mr. Sydney W. Smith remarked that Roberts-Austen had long ago realized the importance of the gold-silver alloys as a means of attacking these problems.

Annealing of Metals

Mr. **F. C. Thompson's** second paper dealt with the annealing of metals.

After briefly considering the structural changes induced in metals and simple alloys by such processes as rolling or wire drawing, as a result of which the crystalline elements remain unchanged in hardness, the conditions governing such mechanical treatment of metals are examined.

The efficient commercial annealing of brasses, nickel-silvers, cupro-nickel, etc., is shown to differ radically from that necessary in the case of steel, the lowering to a minimum of the elastic limit being essential to allow a maximum further reduction at the next rolling before a further annealing is required, and also to minimize the loss of energy wasted in the production of merely elastic deformation.

The course of annealing of hard-worked copper, brass, and nickel-silver, taken as typical examples, is followed in some detail, and the influence of the temperature and duration of annealing, and of impurities in the metal dwelt upon. A summary of Charpy's classical work on the annealing of hard-worked brass, and of similar work by the author on the nickel-silvers is given.

Grain Size Measurements in Metals

A paper sent in by Mr. **Zay Jeffries** of Cleveland, Ohio, on "grain size measurements in metals, and importance of such information," was communicated by the president.

The author emphasizes the value to the user of physical tests of metals. Now physical and mechanical properties of metals vary greatly with changes in structure, and in the cases of pure metals and solid solutions the quantitative estimation of the structure can best be made by determining the grain size. Such measurements, however, only become important when correlated with the physical properties of the metal or alloy. The fact that these measurements do not break down the structure of the metal gives them a distinct advantage over mechanical tests in determining, for example, tensile strength or elastic limits, which are dependent on fineness of grain. The method is one of the best available for the determination of the relative quantities of crystalline and amorphous phases, and it is of special value in indicating the life of metals under vibration, in the estimation of the strength properties of alpha

brass, in indicating hardness, and in all probability in throwing light on certain corrosion problems.

The following methods for measuring grain size are briefly described: (1) the planimeter method, (2) the Heyn method, (3) the intercept method, (4) the method of comparison with known samples, (5) the author's method. This method, for which great rapidity as well as accuracy is claimed, consists in counting the grains completely included and partly included in the circular portion of an image of the specimen of standard magnification, and by means of an empirical formula determining therefrom the equivalent number of whole grains in the standard area. The apparatus and manipulation required for the measurements are described in some detail and a few simple rules for sampling are laid down. In the interpretation of results care must be taken to distinguish between grain-size and cell-size. In cold-worked metals that have been annealed and sometimes in cast metals the grains will often be elongated, but in elongation due to cold-working measurements parallel and perpendicular to the direction of working show fairly constant ratios.

The president, in commenting on the paper, referred to the enormous tenacity attained by metals at extremely low temperatures, due probably to the closeness of grain. It was unfortunate that a limit was soon reached, for instance, in hardened steel, below which the grain was too fine for Mr. Jeffries' method to be applied. He hoped further research would overcome this difficulty; perhaps some method like Bragg's might be applied. He mentioned that whereas a 0.58 per cent carbon steel contained 5540 grains per square inch as forged, and 4500 as forged and annealed, the number rose to 330,000 when the steel was water-quenched and reheated.

Dr. C. H. Desch agreed with the author that the intercept method was not reliable.

Mr. F. C. Thompson, in the course of remarks on the relation of physical properties of iron and steel to grain size, said in these cases another factor had to be considered, namely, the fineness of the carbide in the grains, as well as the size of the grains themselves. He preferred as a unit number of grains per unit length to number per unit surface. Shock tests gave a better measure of crystalline size than tensile tests.

Mr. S. W. Smith suggested that the rate of corrosion might in some cases be used as a measure of grain size.

Specific Heats of Hard and Soft Aluminium

A paper by Dr. **F. J. Brislee**, on "the changes in physical properties of aluminium with mechanical work [II. specific heats of hard and soft aluminium]," was read by Dr. R. Seligman, in the absence of the author.

A series of determinations of the specific heat of hard-worked aluminium and annealed aluminium was made. The metal was used in the form of rod and wire. It was found that the specific heat of the hard aluminium was higher than for annealed, and this confirmed the view that aluminium is converted into an amorphous form by excessive mechanical work. It was further found that the specific heat underwent a change when the hard-drawn bars and wire were heated to 100 deg. C. A sample of wire was prepared by drawing with the maximum draft possible, whereby a high tensile strength was obtained, but the wire could not be bent without fracture. The worked metal had a tensile strength of 18.4 tons per square inch, and after heating to 100 deg. C. for ten weeks the tensile strength was reduced to 13.2 tons per square inch, but whereas the original metal was brittle and could not be used, the metal with the lower tensile strength was quite serviceable.

It is therefore necessary that the determinations of all the physical constants of metals shall be made upon metals in a perfectly definite state and one which can be reproduced. If this is not done, the results are fortuitous and may differ quite widely from the true results.

Further investigation is being made to obtain aluminium wholly in the amorphous state.

Dr. R. Seligman, while agreeing with the author's conclusions, was unable to see how he arrived at them from figures given in the paper. He criticised the author's use of different temperature ranges for the various sets of experiments. Dr. Brislee's observation of the change of the specific heat of hard-worked aluminium under the influence of so low a temperature as 100 deg. C. might possibly be of great technical importance. He did not agree that as a general rule aluminium after ten hours' heating at 500 deg. C. was, although "dead-soft," still largely amorphous in structure.

Dr. J. A. Harker thought it a mistake only to take ordinary temperatures as the norm in studying the relation between composition and physical properties of metals and alloys. If the melting point were taken as the starting point in, say, a series of specific heat measurements, the matter of the previous thermal history of the specimen would not be a disturbing factor. There would be no great difficulty in devising a suitable calorimeter for such measurements.

Annealing of Aluminium

Dr. **R. Seligman** and Mr. **Percy Williams** presented a "Note on the annealing of aluminium."

The authors found that hard-worked aluminium which had been heated for ten hours at 125 deg. C. was less readily soluble in nitric acid than the same metal before heating, but that if the heating were continued for eighty hours, this comparative immunity from attack was lost.

They also found that metal which had been freshly annealed at 440 deg. C. was less readily attacked by nitric acid than the same metal which had been allowed to stand for ten days after annealing.

Dr. H. Borns asked what precautions had been taken to prevent oxidation before making the solubility tests.

Dr. R. Seligman said the samples were all immersed in caustic soda.

Theory of Solutions

Mr. **E. J. Hartung** presented a paper entitled "A contribution to the theory of solution."

The author has tested the divergence in physical properties from those calculated by the simple mixture law shown by two completely miscible liquids which do not visibly react with each other. This divergence has been ascribed by Denison to solvate formation. The liquids used for the experiments were aniline, methyl alcohol, carbon tetrachloride, ethyl ether and chloroform. Measurements were made of the density, heat capacity and heat change in mixing of mixtures of selected pairs of these liquids.

The evidence adduced shows that, in the cases examined, no simple solvate theory will suffice to explain the experimental results, even though the liquids used, with one exception, are little associated. Also, a study of the deviation curves obtained from many other liquid pairs by various authors leads to the conclusion that only in rare cases, if at all, will the conditions be simple enough to permit of an explanation of the deviations by single solvate formation. In the great majority of cases the molecular condition of a mixture of two liquids is much more complex, and it becomes very difficult to develop and apply any satisfactory quantitative theory to such a mixture.

An Electric Arc Furnace for Laboratory Use

BY OLIVER P. WATTS, PH.D.

Several years ago a simple, inexpensive and easily made electric furnace for crucibles was developed in the university laboratories by the writer, and used in the preparation of a large number of iron alloys.* Recently two small arc furnaces of 10 lb. capacity have been constructed for the melting of metals and the making of alloys. Since these are proving well adapted to such use, it is thought that a description of them may be of assistance to those desiring a small furnace for experimental work on a laboratory scale.

In view of the many electric steel furnaces of the arc type now in operation, and the numerous descriptions of these available, it would seem a simple matter to construct a satisfactory furnace for melting metals in the laboratory. This, however, is not so easy as it appears. The small size of the furnace, the short time allowed for melting, and the extremely refractory metals which the laboratory furnace may be called upon to melt, all complicate the problem. The laboratory furnace is far more severe on refractories than commercial furnaces because of the proximity of the sides and roof to the arc, and to the more sudden and frequent heating and cooling, due to its intermittent use. Although heat insulation may be no more important in the laboratory than in the works furnace, on account of its thinner walls, it is desirable to use some special heat insulator in the laboratory furnace instead of employing only the commercial refractory materials used in steel furnaces. The method in which these and other difficulties have been met will be seen in the description.

The nature of the work requires a tilting furnace, which means that the weight should be kept as small as possible. This restricts the furnace to the smallest dimensions which will contain a crucible or melting pot of the desired capacity, and a sufficient thickness of heat insulation. For greater ease of construction and lining with brick, a rectangular form was chosen instead of the more ideally perfect sphere or cylinder.

The furnace body is made of sheet steel ⅛ in. in thickness and is 16½ in. long, 14½ in. wide, and 17½ in. high in front and back, and 11½ in. high on the ends. After the electrodes and lining were in place the ends were raised to the height of the front and back by thrusting pieces of galvanized sheet steel down inside the end walls. If another furnace were to be designed the walls would all be made of the same height with slots in the ends to accommodate the electrodes.

Refractories

Due to the severe usage to which it must be subjected, magnesia was the only material considered for the melting pot, which was constructed of magnesia brick 2¼ in. thick. The corners were filled with a cement of electrically fused magnesia moistened with a solution of sodium silicate, so that there might be no places for metal to lodge when the furnace is tilted for pouring. The melting pot is 8¾ x 6 x 7 in., and has a capacity of 12 lb. of metal. By setting the electrodes higher its capacity could be increased to 18 or 20 lb. if desired.

Although magnesia brick are so refractory that they give no trouble from melting, as a roof for a small arc furnace they last only a few heats. They usually crack across the middle the first heat; with further use other cracks form, pieces drop out, and the roof soon fails. A new departure was therefore tried for the roof. A lump of electrically fused magnesia was prepared in a 60-kw. arc furnace. This was sawed in two by the Grant Marble Company of Milwaukee, producing two slabs of a beautiful crystalline structure, 11 x 8 x 2¼ in., weighing about 20 lb. each. One of these slabs was used for the roof of each of the two furnaces already constructed. One of the furnaces has been operated seven afternoons with no apparent injury to the roof, although one day a temperature of 2190 deg. C. was measured inside the furnace with the power off. Graphite is the only other material ever used by the writer which could have withstood such service, and graphite was impossible for the roof of this furnace, from the standpoint of oxidation, of electrical conductivity, and of contamination of the charge.

Heat Insulation

The high thermal conductivity of magnesia brick and fused magnesia when hot made it necessary to provide special heat insulation. Infusorial earth, usually considered the best insulator, could not be employed because the temperature would occasionally be far above the melting point of silica. Magnesia is an important ingredient of the insulation commonly used on steam pipes, but it cannot be used here. Effective insulation depends on porosity—on a multitude of air cells in the insulating material—and magnesia frits to a solid mass at temperatures occasionally attained by the melting pot of these furnaces. The insulating material must not only retain its porosity at extremely high temperatures, but it must not flux with magnesia at, or even above, 2000 deg. C. Previous experience had shown that air-slaked lime fulfills these severe requirements to a remarkable degree, and this was therefore chosen for the insulator. Since enough of this could not be obtained promptly, an exceptionally pure lime was slaked to dryness by the minimum amount of hot water.

Two inches of slaked lime was tamped into the furnace, and the melting pot previously described was built upon this. The space between the pot and the steel shell, 2 in. at the ends and 3 in. at front and back, was also filled with slaked lime. In order to pour the metal it was necessary to build a bridge of magnesia from the melting pot to the spout, and to cover this the roof of fused magnesia extended forward within ¼ in. of the shell of the furnace, making two breaks in the heat insulation. The roof was covered to a depth of 2 in. with slaked lime, and a sheet of asbestos and a wire screen were placed over the top to hold the lime in place when the furnace is tilted.

Fig. 1 shows the furnace before the roof was put on.

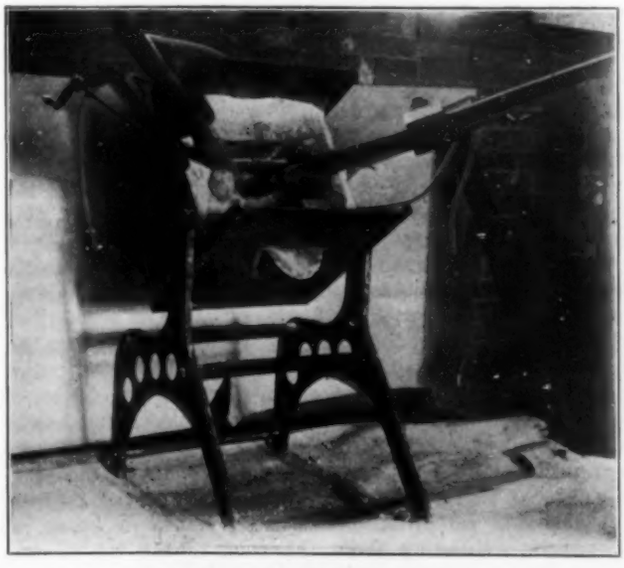

FIG. 1—ELECTRIC FURNACE BEFORE ROOF IS PUT ON

*Electrochemical & Metallurgical Ind. 4, 273 (1906).

and Fig. 2 is the completed furnace, except that the steel shell was cut away over the spout to a height of 3 in., so that the spout can be used as a charging door. This is closed by a magnesia brick when the furnace is in operation. The total weight of the furnace is 334 lb., yet it is readily tilted for pouring by one man. Exclusive of refractories the cost was $50 each. The linings were put in by students as class exercises.

Electrode Holders

The electrode holder is shown in Fig. 3. This consists of a casting of red brass, bored for a 1½-in. electrode. The top of the holder is split, and can be clamped to the electrode by means of two stout screws. Water-cooling is essential, and was provided for by drilling holes in the holder and inserting small copper tubes to which pieces of ¼-in. rubber tubing are attached. One of these connects the holders with each other; to the others standard hose couplings are permanently fastened for convenience in attaching the ½-in. hose by means of which water is carried to and from the furnace. The electrodes are moved by a screw feed actuated through pinions by a crank beneath the electrode. Since it would often be desirable in melting metals to

FIG. 2—COMPLETED ELECTRIC FURNACE

operate without a slag, the usual vertical arrangement of the electrodes in steel furnaces was not desirable, and the electrodes were inclined so that they meet at an angle of 90 deg. above the furnace charge. This arrangement has proved satisfactory, although through carelessness students sometimes feed one electrode too far into the furnace, so that the arc plays upon the side instead of the tip of the electrode, and they may even push an electrode into the metal. This technical defect has an educational value, for it is not well that students should work with foolproof apparatus. On account of their position, there is a tendency for the holes in the roof through which the electrodes pass to act as chimneys, and cause a draught of air through the furnace; this results in undue oxidation of the electrodes unless a packing of asbestos or similar material is placed around the electrodes where they pass through the roof. To prevent the loose lime on the roof from falling into the furnace when an electrode is removed, tubes of magnesia, extending from the roof to the top of the layer of lime, were built around the electrodes.

Electrodes

On account of the space occupied the diameter of the electrodes was fixed at 1½ in., as the largest size that could well be used. It was expected that at 20 to 25 kw. carbon electrodes could be used without their heating to the temperature of oxidation outside of the furnace, while on the few occasions when more power must be used graphite electrodes could be substituted.

The advantages of carbon electrodes are:

1. Lower cost.
2. They are obtainable in 3-ft. lengths, instead of the maximum of 2 ft. for graphite, thus greatly lessening stub-end waste.
3. Their poorer thermal conductivity results in much less heat loss than with graphite electrodes of the same diameter.

By maintaining the voltage above 75 it has been found possible to use 20 kw. without serious oxidation of carbon electrodes. This is sufficient power for most purposes. For 25 to 30 kw. graphite electrodes are employed.

Although the electrodes have been referred to as passing through the roof, they really emerge from the end walls of the furnace. There are no holes in the slab

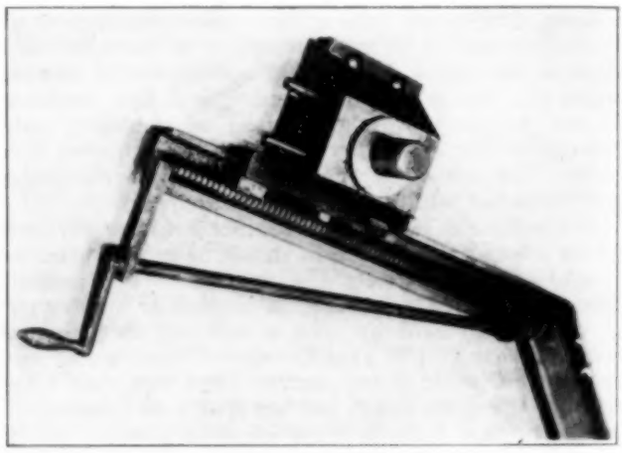

FIG. 3—ELECTRODE HOLDER

of fused magnesia, which just fills the space between the electrodes. The end walls are built up around the electrodes to the level of the roof with the cement of fused magnesia and sodium silicate solution previously referred to.

Operation

In melting metals it is desirable to heat the furnace before putting in the charge, in order to shorten the time that the metal is subjected to possible contamination by carbon from the electrodes or by oxidation. It is advisable to use a mold that can be lifted to the spout of the furnace, thus avoiding the loss of material and likelihood of freezing, incident to the use of a ladle with such small quantities of metal.

An alloy of nickel, chromium and tungsten, contain-

TABLE

Time	Kw.	Volts	Interval
2.15	30	70	
0.25	30	70	
0.40	20	81	
0.45	25	Charged 10 lb. of iron.	30 min.
3.00	22.5	80	
0.09	Poured and recharged 10 lb.		24 min.
0.15	22.5	80	
0.20	25	78	
0.27	Poured and charged 10 lb.		12 min.
0.31	Restarted.		
0.35	25	70	
0.50	Poured and charged 10 lb.		19 min.
0.54	25	70	
4.05	20	68	
0.07	Poured and charged 10 lb.		13 min.
0.10	20	64	
0.22	Poured.		12 min.

ing 40 per cent of the last metal, was cast directly into a mold without difficulty.

The log of a furnace run on cast iron is given in Table I.

Power was on the furnace for an hour and thirty-six minutes, and 35 kw.-hr. were required to melt and pour six heats, totaling 50 lb. of metal. The time required for the successive melts is shown at the right.

At another time when using 30 kw. 11½ lb. of cast iron was melted and poured in six minutes after the furnace was well heated.

To test the effectiveness of the heat insulation mercury thermometers were placed against the back and one end opposite the melting pot, and covered with steam-pipe insulation. The furnace was then heated, and at intervals the current was interrupted and the temperature within the furnace was measured through a hole made in the door made for this purpose by means of a Holborn-Kurlbaum optical pyrometer. The log of the run is given in Table II.

TABLE II
LOG OF TEST

Time	Kw.	Volts	Temperature Outside, Back	Temperature Outside, End	Temperature Inside
2.30	26	90			
0.35	30	80			
0.40	35	45			
0.45	30	88			
0.55	37	64			
3.00	37	64			
3.08	0	0	48 C.	40 C.	1920 C.
0.15	37	64			
0.25	0	0	77	61	2130
0.30	37	64			
0.40	0	0	106	88	2190
0.42	20	80			
0.47	0	0	142	102	
4.02	0	0	180	114	1600
0.10	0	0	194	124	1500
0.25	10	102	219	142	1395
0.30	30	90	235	157	
0.45	28	90	251	178	
0.52	0	0	256	183	1990
0.53	28	90			
5.05	0	0	272	196	1990
0.06	24	92			
0.20	0	0	292	214	2150
0.28	0	0	313	228	1760

Interruption of the current is indicated by zero values for kilowatts and volts; the time of restarting is shown by the next significant figures in these columns.

Although the lime insulation did not melt under this severe test, it shrunk considerably over the center of the roof, and a red hot spot at that point required the addition of more lime during the test. Most of the heat loss indicated by the rapid cooling when the current was cut off at 3.47 occurred around the spout. The heat conductivity of fused magnesia proved so great that the steel shell was entirely melted away in front of the roof; a small piece of the spout was also melted. The only serious damage was caused by the melting of a portion of a very refractory alumina brick used as a door during a part of the test. This ran down inside the furnace and fluxed the bottom. For operating at this high temperature better insulation of the front of the furnace is required, and can be secured by lessening the thickness of the magnesia which extends through the insulation to the shell, and by covering the outside of the magnesia door by a heat insulator.

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Instruments for Recording Carbon Dioxide in Flue Gases.—The Bureau of Mines has undertaken the testing of several different types of apparatus for the analysis of flue gases and published the results in Bulletin 91. Awakened activity in power-plant economies has brought many new forms of carbon dioxide apparatus on the market. The tests were made under service and laboratory conditions and the results show the factors which may affect the accuracy of a CO_2 recorder and the manner in which a recorder should be tested.

The Sherardizing Process

BY OLIVER W. STOREY

The present conflict in Europe has caused a spectacular rise in the price of most metals. Zinc has been one of those affected, the present price being about 13 cents compared with 6 cents under normal conditions. Zinc dust, or the so-called "blue-dust," necessary for the sherardizing process, has jumped from 7 to 40 cents with little available. Users of the sherardizing process are necessarily interested, with the present high price of zinc dust, in securing a maximum of protection with a minimum expenditure of zinc. It is the purpose of this article to show how this may be best accomplished, together with an explanation of the fundamental principles involved.

It has been within the past decade that the sherardizing or "dry galvanizing" process has taken its place among the many methods used to protect iron and steel against corrosion. The method of applying the zinc is different from either the electro or hot galvanizing processes. It is applied by heating the objects to be coated in finely divided zinc to a temperature well below the melting point of zinc. When the process is properly carried out the resulting coating is hard and crystalline and consists of an iron-zinc alloy high in zinc which protects the iron base.

The finely divided zinc used for the sherardizing process is usually the so-called "blue dust" obtained as a by-product from the zinc smelter. This "blue dust" is a zinc dust of extreme fineness, each metallic zinc particle being covered with a film of oxide. A prepared "sherardizing zinc" is also on the market consisting of practically pure zinc powdered to about 100 mesh fineness. This is often used in connection with "blue dust" but is probably never used alone. A granular zinc-iron alloy[1] of the composition $FeZn_{10}$ is used to a limited extent.

The sherardizing process is the invention of Sherard Cowper-Coles, an Englishman. While the first patents were granted about fifteen years ago, it was not until 1908 that the first commercial plant was in operation in the United States. Since then the process has come into extensive use for certain classes of articles.

The articles that are most successfully treated are nuts, bolts, screws, nails, pipe fittings and the like, small castings and various intricate shapes which cannot be perfectly coated by the older processes. Sherardizing is especially adapted to small articles that can be loaded into drums and afterward separated from the dust by screening. Pipes are also being successfully coated both on the interior and exterior. Large flat pieces such as sheets are treated with difficulty. Up to the present time continuous sherardizing of wire and similar products has not been entirely successful.

The principles involved in the sherardizing process were not entirely unknown previous to the time of Cowper-Coles' patent, for in 1838 Miles Berry took out a British patent in which he coated iron and copper in a manner similar to the present process. Various other patents of a similar nature were granted from time to time, but none of commercial importance. The ancients hardened copper in a manner similar to the present cementation process for carbonizing iron and resembling the methods employed in sherardizing. In certain localities they placed the copper in the ground which was heated for a period of time by building fires over the place. Needless to say the ground in these favored localities contained zinc or tin ores. Brass was made, up to the beginning of the last century, by heating cop-

[1]Burgess, C. F., Coating Iron by Applying Granular $FeZn_{10}$ and Heating. U. S. Patent No. 1,014,749.

per in contact with zinc ores, a process similar to sherardizing.

At the present time the process is carried out in the following manner. The articles, previously cleaned of all dirt, scale, or grease, are imbedded in a drum of suitable zinc dust and are heated for the proper length of time to the correct temperature, removed from the furnace and allowed to cool. The zinc dust is then separated from the coated articles by screening. As the metallic content of the zinc dust drops, it is maintained at the proper percentage by the periodic addition of new dust. Theoretically this is a comparatively simple process.

Unfortunately when sherardizing was first introduced into this country many extravagant claims were made for the process as is so often done with new inventions. As the process came into use there were many disappointments because these extravagant claims were not borne out in practice and as a result the commercial development was slow until the nature of the process was understood and its limitations ascertained. The statement that "the sherardizing process adds nothing to the surface of the article" caused the greatest amount of trouble. The claim was made that "you can take a screw from your watch—sherardize it, and you can replace it again without rethreading." Where screw-threads were sherardized on this assumption, the indignation and wrath of the manufacturer may be imagined when threads came back for recutting. As zinc is added to the surface of the iron due allowance must be made for it.

While the sherardizing process has been in commercial use for almost a decade, it is doubtful whether the average quality of sherardizing has been improved during that period except in a few instances where a thorough study of the process has been made. In making tests of the work turned out by various manufacturers, the writer has found that the quality varies greatly. In some cases, the protection afforded, even with a heavy deposit, was small while in other instances thin coatings were practically indestructible under ordinary weathering conditions.

The difference in quality of the different deposits is caused by a difference in the methods used for the deposition of the zinc. A lack of understanding of the effect of the relation of time, temperature and metallic content of the dust on the quality of coating formed has resulted in the deposition of poor coatings. To fully understand the relation of the above variables to the quality of the coating it is necessary to know the nature of zinc-iron alloys.

Alloys of Iron and Zinc

The exact compositions of the alloys of zinc and iron are not known. The solubility relations of the two metals have been studied by Wologdine[3] and von Vegesack[2] but the results of these two workers are not entirely in agreement.

Both investigators show that iron is totally insoluble in zinc in the solid state. The freezing point of the zinc increases rapidly with increase of iron. The first freezing occurs at 419 deg. for the pure zinc which rises to 755 deg. at about 8 per cent of iron. Both diagrams show that pure zinc separates out from the alloy up to about 7 per cent of iron.

The diagrams beyond 8 per cent of iron are not in agreement. Wologdine shows that at this point the freezing temperature reaches a maximum after which the curve drops again. Unfortunately he did not work with alloys containing more than 10 per cent of iron. With more than 9 per cent of iron a secondary freezing took place at 685 deg. This would seem to indicate that an eutectic occurs at between 10 and 11 per cent of iron. The maximum point on the curve at about 8 per cent would seem to indicate that a chemical compound is formed which would have the composition $FeZn_{10}$ and which Wologdine succeeded in isolating. This compound appears to dissolve a small amount of zinc though the data are incomplete on this point. At above 8 per cent of iron it seems to form an eutectic with one of the compounds richer in iron.

Von Vegesack's diagram, on the other hand, shows no discontinuity at 8 per cent, the freezing point increasing steadily with an increase in iron content. At 10.9 per cent, he shows that the compound $FeZn_7$ is formed which corresponds closely with Wologdine's eutectic at 685 deg. The compound $FeZn_7$ is shown to dissolve between 3 and 4 per cent of zinc in the cold so that the point of maximum solubility of these two constituents is between 7 and 8 per cent of iron corresponding to the $FeZn_{10}$ of Wologdine's diagram. Von Vegesack also shows that the compound $FeZn_7$ is formed.

If iron is added to a bath of pure zinc at a temperature slightly above the melting point of the latter it will dissolve readily. If about 4 per cent is dissolved, which gives the alloy the consistency of ordinary galvanizer's dross, and is examined under the microscope, the alloy will be found to consist of a number of brilliant, hard, definite crystals imbedded in a matrix of pure zinc. With 4 per cent of iron these crystals cover about one-half the field. If these crystals, which are much less soluble in acids than the pure zinc matrix, are analyzed, they will be found to contain about 8 per cent of iron. As the percentage of iron in the alloy is increased and the amount approaches 8 per cent the entire alloy consists of these crystals. On the other hand as low as 0.07 per cent of iron in zinc can be detected under the microscope by these crystals.

This 8 per cent alloy is peculiar in its properties. If it is melted and allowed to cool in a crucible, the freezing proceeds normally. When it cools to a low red heat after freezing, recrystalization takes place and the alloy, if not under pressure, will expand and break the crucible. If the alloy is allowed to cool in a spelter mold it will rise very much like a loaf of bread. If the metal is of the correct composition, it then will crumble and consist of a mass of loose crystals.

These crystals may also be made by tumbling the requisite amount of iron with zinc kept at just above the melting point of the latter. A loose mass of brilliant crystals will result.

Whether the peculiar alloy formed at 8 per cent of iron is the compound $FeZn_{10}$ or whether it is a solution of zinc in $FeZn_7$ cannot be definitely settled until the solubility relations of the two metals have been rechecked.

By analogy it appears that the brittle alloy containing 8 per cent of iron should be a definite compound, $FeZn_{10}$ and not a solid solution of zinc in $FeZn_7$. It is known that solid solutions are perfectly homogeneous and malleable[4] and all industrial alloys which are capable of being cold rolled, drawn, or spun, are solid solutions. Eutectics are more or less brittle and intermetallic compounds have the same property. The $FeZn_{10}$ is of definite crystal form and extremely brittle and has none of the properties of a solid solution and all the properties of an intermetallic compound.

The meager and conflicting data on the solubility relations of zinc and iron make the exact nature of the al-

[3]Wologdine, S., The Alloys of Zinc and Iron. Revue de Metallurgie, Vol. 3, 1906, p. 539.
[2]Von Vegesack, A., Zeit. anorg. chem., Vol. 52, 1907, p. 30.

[4]Law, E. F. The Failure of the Light Engineering Alloys, Particularly the Aluminium Alloys. Trans. Faraday Soc., Vol. 6, 1911, p. 185.

loys formed in sherardizing of some doubt. Before the process can be fully explained these data will have to be obtained.

The swelling of the zinc-iron alloy is not peculiar to it alone, but has been noted in several other alloys, for example, in one of iron and aluminium.[4]

Iron Content of Sherardized Coatings

Several investigators have made a study of the zinc-iron alloys formed in the sherardizing process but the conclusions reached have differed. These investigators have found the iron content to vary from 9 to 30 per cent and the coating to consist of from 1 to 4 layers of different zinc-iron alloys. A result of these conflicting statements is that it is difficult to understand the exact nature of the coating formed in the sherardizing process.

These conflicting results obtained may be correlated when it is shown that the iron content of the sherardized coating is a function of the temperature used, which in turn is determined by the percentage of metallic zinc in the dust. If the investigators had given these data their results would have shown the alloys that were formed at different temperatures and concentrations of zinc.

The writer has determined to a limited extent the effect of temperature on the iron content of sherardized coatings. The analyses were made on coatings of approximately the same thickness. The time of deposition was the same while the concentration of zinc in the dust determined the temperature necessary to secure the necessary thickness of coating. Unfortunately it was impossible to secure accurate temperature measurements as the experimenting was done with large drums traveling through a tunnel type furnace.

The metallic content of the zinc dust varied from 18 to 42 per cent, the variation in temperature necessary for these extremes being about 65 deg. C., the higher metallic content requiring the lower temperature. With a metallic content of 18 per cent the iron content was 22.45 per cent while with a metallic content of 42 per cent the iron content of the coating dropped to 11 per cent. These percentages were obtained with a coating of about 0.6 ounce per square foot. The data obtained with intermediate metallic percentages showed that the iron content of the sherardized coating is proportional to the temperature used, the rate of deposition being constant. Tests were not carried out to determine the composition of the coating with a dust of varying metallic percentages at a constant temperature.

From the above data the variation in iron percentages reported by earlier investigators and the differences under the microscope are explained. The investigation of the sherardized coating with reference to its structure is incomplete without a knowledge of the depositing conditions.

The higher the temperature of deposition the higher the percentage of iron in the alloy provided the rate of deposition is the same. The increased quantity of the base metal alloyed with the zinc at the more elevated temperatures is easily shown when copper is sherardized. Here the colors are such that the resulting alloys are easily recognized.

When a piece of copper is sherardized at a comparatively low temperature, about 300 deg., the coating will consist of a hard silvery alloy with traces of an intermediate yellow alloy. This hard silvery coating of copper and zinc cannot be "touched" by a file and will take a high polish.

If the copper is sherardized at a comparatively high temperature, 400 deg., and then cooled slowly, the coating will be found to consist of two definite layers. The outer layer will consist of the hard, silvery, crystalline alloy previously mentioned while the intermediate layer will consist of an alloy having the color of yellow brass. These two alloys, together with the copper base, form definite layers that do not merge into each other with a gradual gradation of color but are sharply defined as though formed by the piling up of sheets of vari-colored metal. No pure zinc was found at any time on the surface.

When etched and viewed under the microscope the junction of the three layers, copper, brass and white metal, reveals another peculiarity. The structure of the outer two layers is granular like that of pure annealed iron while that of the copper is less definite. The dividing line between the yellow and white brass does not follow the grain outlines but cuts across these grains. The granular structure of the two brasses is continuous.

An analysis of the two layers, these results being checked on several specimens made in different heats, showed that they were of definite composition. The outer silvery layer showed a composition of about 67.3 per cent zinc and 32.7 per cent copper which corresponds to the formula $CuZn_2$, while the inner or yellow brass layer corresponded to the formula CuZn or about 50.7 per cent zinc and 49.3 per cent copper. If the heating is prolonged enough, the entire specimen changes to $CuZn_2$.

By heating the copper and zinc dust to various temperatures and for different periods of time it was thought possible to form other layers than those mentioned but the above alloys always resulted.

From the above data it appears reasonable that copper and zinc form two definite intermetallic compounds at sherardizing temperatures, CuZn and $CuZn_2$, and that no others are formed. These data should be of help in interpreting equilibrium diagram data for the copper-zinc alloys.

The results obtained in sherardizing copper show that the higher temperature results in a higher copper content of the coating and that the alloys formed are in definite layers, each having a definite composition corresponding to an intermetallic compound.

Since iron and zinc and their alloys are of the same color it is difficult for the eye to detect distinct layers on sherardized iron. For this reason, the layers cannot be removed as readily and analyzed. But by proper polishing and etching methods, the sherardized iron structure may be studied.

Since the solubility data on iron-zinc alloys are conflicting it is impossible to know what compounds and solutions these metals form. Without these data it is impossible to assign a definite composition to the layers formed on sherardized iron. By analogy to the copper-zinc results it is reasonable to suppose that with low temperatures a high-zinc alloy will be formed while at high temperatures a high-iron alloy will be formed.

Burgess[5] in his investigation of the sherardized coating shows but one main layer to be formed. This layer, by analysis, corresponds closely to the formula $FeZn_{10}$. Only a very thin film of relatively pure zinc is formed on the exterior while there is an indication of a thin alloy between the $FeZn_{10}$ and the iron. This thin alloy is probably higher in iron. That the samples used by Burgess were made at a low temperature is indicated by the low iron content. The $FeZn_{10}$ compound, when alloyed to the iron, has a peculiar fissured appearance. This appearance is due to the peculiar crystallizing effects previously noted when this alloy is cooled from the molten state. This compound is shown by Burgess to be present also in hot galvanized iron.

Arthur and Walker[6] show that the main layer formed in sherardizing under certain conditions of time, tem-

[5]Burgess, C. F. Sherardizing Magazine, Vol. 1, March, 1910.
[6]Arthur, W., and Walker, W. H., Structure of Galvanized Iron. Jour. of Ind. Eng. Chem., Vol. 4, 1912, p. 397.

perature, and concentration of zinc dust, consists of the peculiar fissured alloy previously noted by Burgess. They also point out that a second thin alloy high in iron is formed between the main alloy and the iron base. They assign the formula $FeZn_7$ to this material. They also state that if the time of deposition is lengthened and a dust high in zinc is used a layer of pure zinc will form on the exterior of the sherardizing. Definite proof of the composition of the various alloy layers investigated is lacking, owing to the absence of reliable solubility data.

In their description of the structure of galvanized iron Arthur and Walker show that crystals of the iron-zinc alloy are present in the zinc. The formation of the alloys between the iron and zinc is also noted.

The structure of the sherardized iron depends entirely upon the time, temperature, and concentration of the zinc dust used. With the high temperature necessary with a lean zinc dust alloys high in iron will be formed on the surface. With a rich zinc dust and a low temperature the alloy formed will be high in zinc and may have some free zinc on the exterior though this layer of zinc will be thin. Johnson and Woolrich[7] state that it is impossible to sherardize pure zinc which would seem to indicate that it is impossible to obtain a coating of pure zinc of any appreciable thickness on the exterior of sherardized iron.

Theory of Sherardizing

Several theories have been advanced in trying to explain the formation of the coating in the sherardizing process. None have been entirely satisfactory.

Hinchley[8] advances the explanation that the magnetic oxide is first formed in the heating of the articles and that this oxide is subsequently reduced by the metallic zinc with the formation of zinc oxide and the zinc-iron alloy. But when it is shown that sherardizing can be carried out more easily in a vacuum where the magnetic oxide is not formed, this theory does not hold.

The vapor theory, which has been generally accepted as explaining the mode of zinc deposition, states that the zinc vapor present, due to the slight, though appreciable vapor pressure of less than 0.100 millimeter, is sufficient to allow enough zinc to be condensed on the iron to form the protective alloy. Although the vapor pressure of zinc at sherardizing temperatures is almost negligible that of the finely divided zinc or blue dust is several times greater. That this is the cause of the relatively higher rate of deposition than could be obtained from ordinary zinc is the basis of the vapor theory.

The vapor theory is not without objections. The writer has experienced much trouble in the sherardizing of large pieces of flat work in non-revolving boxes. If the dust was not in close contact with the entire area those parts which were not touched by the dust were not sherardized. Hinchley[8] also states that if a cavity of 0.001 in. is left about the article to be sherardized only the points of contact are acted upon. In commercial sherardizing, zinc oxide in varying amounts is often found enclosed in the coating which would not be probable if it were purely a vapor process.

The sherardizing process should not become confused with the vapor coating process. The inventor of the sherardizing process also coats iron or steel by subjecting it to the vapors of zinc at a temperature which is much higher than that used in the sherardizing process. But with the low vapor pressure of zinc, at the sherardizing temperature, even in the form of dust, the amount of condensation or other vapor alloying action must be small, and it does not seem reasonable to attribute the large amount of metal deposited to the vapor alone.

If strips of polished copper and zinc are clamped together so that considerable pressure is exerted between the two pieces, and these are then heated to about 350 deg. C. for about twenty minutes, the copper strip will become covered with a white alloy, $CuZn_5$, showing that alloying has taken place.

If two similar strips, placed together but under no pressure, are heated in a non-oxidizing atmosphere, no alloying or welding action is observed and the copper is uncolored by the zinc except at the points of contact. Intimate contact obtained by pressure was required in the first instance to secure alloying action, while in the second, though the metals were in close proximity, no action took place. If a vapor formed no evidence of condensation is visible on the copper. Copper is used in these experiments because of the color formation which makes the alloying action easy to detect.

The metal zinc is chemically active when compared to the other common metals, such as tin, lead, copper, nickel and iron. This property is common to the three metals of the subdivision of the periodic group to which zinc belongs. Mercury and cadmium are the remaining members.

The chemical activity of mercury and the ease with which it forms alloys or amalgams with many metals is a universally known property. Zinc is next to mercury in its chemical activity while cadmium is the least active.

From our knowledge of the similar properties of the elements in a periodic group we would expect zinc and cadmium to have properties similar to mercury, but to be less active. This is found to be the case. While mercury amalgamates or alloys with many metals in the cold, there is but one metal, gold, with which zinc will amalgamate or alloy with in the cold.

If a thin film of gold is plated onto zinc and allowed to stand for a few weeks at atmospheric temperature the gold will have completely disappeared and become alloyed with the zinc. Other metals will alloy with zinc in a similar manner, but require a more elevated temperature.

In considering the sherardizing process and the alloying action of zinc and iron at relatively low temperatures, it becomes necessary to consider similar results obtained with other metals.

In 1896 Roberts-Austen[9] showed that it was possible to alloy gold and lead at temperatures well below the melting point of lead, and even at temperatures below the boiling point of water. At higher temperatures the process is much more rapid so that gold is able to rise against gravity to a height of 7cm. in lead at 250 deg. in less than a month. The latter temperature is 77 deg. below the melting point of lead.

Gold[10] diffuses in silver at 800 deg., the diffusivity being of the same order as that of gold in lead at 200 deg.

Spring[11] showed in 1894 that carefully surfaced cylinders of copper and zinc, heated six or eight hours at 400 deg., formed a layer of yellow alloy to a depth of 0.8 mm.

In considering the theory of the deposition of zinc in the sherardizing process some experiments taken from a thesis on "sherardizing" submitted by the author at the University of Wisconsin in 1910 will be of interest.

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[7]Johnson, A. R., and Woolrich, W. R. Zinc Cementizing, Trans. Am. Electrochem. Soc. Vol. 21, 1912, p. 561.
[8]Hinchley, J. W. Some Practical Experience with the Sherardizing Process. Trans. Faraday Soc., Vol. 6, 1911, p. 133.

[9]Roberts-Austen, Phil. Trans. Vol. 187A, 1896, p. 383.
[10]Desch, C. H. Metallography, 1910, p. 217.
[11]Spring, W. Bul. Acd. roy. Belg., Vol. 28, 1894 (III), p. 23.

Antimony was found to behave in a manner similar to zinc, and iron could be easily coated by antimony at the low temperatures used with zinc dust. The antimony used was the ordinary commercial material which had been granulated in a mortar. The antimony also coated copper easily, and formed two layers, one of which was identified as the purple $SbCu_3$. Zinc specimens were coated by the antimony while antimony could be sherardized in zinc dust. The coatings on the zinc and copper specimens formed by the antimony were loose and adhered but slightly to the base.

Aluminium could not be sherardized with zinc or antimony at the temperatures used.

Aluminium dust did not coat iron or zinc, but copper was affected and turned a golden color. (Iron may be coated by aluminium by a process similar to sherardizing in the so-called calorizing process, though the temperature is above the melting point of aluminium.)[12]

Copper powder used as a sherardizing material did not coat, probably due to the formation of the oxide.

Arsenic coated both the zinc and copper heavily and easily, while iron was not affected by it except at higher temperatures than those used for sherardizing.

In view of the above data showing that sherardizing may be carried out with various metals, especially antimony, at temperatures used ordinarily in sherardizing with zinc dust, and where the vapor tension is practically nil, it does not appear that the action in the case of zinc should be entirely different. If the action of antimony or aluminium is by contact why should not the action of zinc be that of contact? While the vapor may play a small part in the case of zinc, especially when the temperature approaches the melting point, it is probably mostly contact action. This action will probably occur most readily where inter-metallic compounds are formed, and for this reason the sherardizing may be a measure of the affinity of certain metals, and may be of use in determining the constitution of alloys.

Desch[13] states that: "Microscopical examination shows that union takes place particularly between those metals which form inter-metallic compounds, but that the typical eutectic and other structures characteristic of solidified metals are not produced. The fact of union is most patent when metals which form colored compounds, such as copper and zinc, or copper and antimony, are heated together."

The data show that the formation of alloys below the melting point depends almost entirely on the formation of inter-metallic compounds. A few exceptions are noted where solid solutions are formed as in the case of gold and silver. Our information on the composition of alloys is too meager to formulate any definite law. This phase of the study of the formation of alloys has barely been touched upon and offers a rich field for further research.

Diffusion also plays an important part in sherardizing and in the formation of alloys below the melting point of the constituent metals. After the first alloying at the surface of the metals takes place solid diffusion commences. The two metals diffuse through the alloy formed from a place of higher to lower concentration until equilibrium is attained.

Zinc has the property of forming compounds with many of the metals and this activity is probably the basis of the sherardizing action. Without the ability to form compounds it is doubtful whether the reactions involved in sherardizing would occur below the melting point of zinc. This is illustrated by the action of powdered zinc on copper.

Copper and zinc form a series of solid solutions when melted together. Yet when copper is sherardized under varying conditions two compounds are invariably formed, CuZn and $CuZn_3$. No other proportions of the two metals have been found.

One of the principles involved in chemical reactions is that a more finely divided material is more active than one less finely divided since a more intimate contact between the reacting materials is obtained. The finely divided zinc dust is in such shape that it is in more intimate contact with the article to be sherardized than ordinary granulated zinc would be and this is borne out in sherardizing practice. The ordinary "blue dust" adheres so well to any surface that it can only be removed with difficulty. Many chemical reactions cannot be carried out successfully unless the materials are finely divided and in intimate contact.

Johnson and Woolrich[7] show that when the articles are not tumbled finely divided zinc dust is not as rapid in its action as a coarser dust. But the opposite seems to be true from practical experience when the container is revolved. If the container remains stationary they show that with zinc dust of 100 to 150 mesh fineness it is deposited nearly twice as rapidly at 370 deg. C. in three hours than with the finest zinc dust. The coating obtained with the coarser material was much rougher as is often found in commercial practice. It is also stated that the coarse zinc dust particles had a tendency to fuse together at that temperature.

The above statement shows that the zinc at the sherardizing temperature is more or less plastic and can be easily welded or joined to other metals in the same manner that iron, platinum and other metals may be welded together well below their fusing temperature. By the vapor theory the coating should not be rough but this work shows that the zinc particles actually become welded to the iron or the alloy and in that way quickly form a rough and heavy coating. This welding action is aided by the formation of the inter-metallic compounds.

When an article is tumbled with coarse zinc, the inter-metallic welding action cannot be carried to completion due to abrasion in contrast to the opposite condition when no tumbling occurs. This explains the high rate of deposition for coarse particles obtained by Johnson and Woolrich in comparison to the finer zinc dust. In commercial practice the finer particles react more quickly and are welded and alloyed completely with the iron before they can be removed by abrasion.

The necessity of intimate contact is again shown by Weyl's[14] experiments in which he carbonized iron with pure carbon by contact at temperatures above 1000 deg. C. in a vacuum. Here the reaction between iron and carbon to form iron carbide did not take place until intimate contact between the iron and carbon was secured. No gases were necessary to carry out the carburization.

In the same way, a low-carbon and high-carbon steel may be heated in contact with each other[15] and no transfer of carbon from the high to the low carbon steel will result unless the surfaces were previously polished and pressed firmly together. These surfaces ultimately weld together.

The various instances given show that metals unite below their melting points under proper conditions and by analogy the active zinc will unite with iron, copper, nickel, and other metals below its melting point because of the affinity of the metals involved as shown by the inter-metallic compounds formed.

Johnson and Woolrich,[7] in support of the vapor theory,

[12]Ruder, W. E. Calorizing Metals. Trans. Am. Electrochem. Soc. Vol. 27, 1915, p. 253.
[13]Desch, C. H. Metallography, 1910, p. 219.

[14]Weyl, Fritz. Cementation in a Vacuum by Means of Pure Carbon. Metallurgie, Vol. 7, p. 440.
[15]Adams, F. W. The Diffusion of Carbon in Iron. Engineering, Vol. 100, 1915, p. 95.

carried out experiments in which they sherardized iron with various alloys of zinc that contained small percentages of other metals. Those mentioned were zinc-aluminum, zinc-tin, and zinc-iron ($FeZn_{10}$). The rate of deposition of coats on iron or copper from these alloys was less in every case than for pure zinc. They also found that if copper was sherardized with $FeZn_{10}$ the white alloy formed below the melting point of zinc contained no iron while with increasing temperatures above this the percentage of iron increased. These data are not entirely in accord with results obtained by other investigators. Where the diluting metal does not form an inter-metallic compound with iron or zinc it probably will not be found in the resulting coating. While the data presented are not in conflict with the vapor theory they also are in accord with the contact theory.

The presence of a second metal will dilute the zinc so that the action will not be as rapid if the metals used do not form compounds directly with the iron. The character of the diluent, whether it is sand or a metal, is not of moment, provided it is not as active toward iron as zinc.

While engaged in commercial work in sherardizing the writer had occasion to make some 15 to 20 tons of $FeZn_{10}$ for sherardizing purposes. It was found that by the addition of from ½ to 1 per cent of aluminium the oxidation was cut down appreciably and the coating was much whiter. An analysis of the coating formed on iron showed aluminium to be present. This does not bear out the experiments of Johnson and Woolrich[7] who state that aluminium when present in the coating medium will not be found in the coating if the temperatures are kept below the melting point of zinc.

Hinchley[8] also states that if other metals, whose oxides are reduced by zinc, are present in the zinc dust, these metals will appear as impurities in the coating.

The writer found that if the white zinc-copper alloy, $CuZn_5$, containing 31.9 per cent copper, formed when copper is sherardized, is used for the coating of iron no action takes place even at a low red heat. On the other hand copper is readily coated by means of the iron-zinc alloy, $FeZn_{10}$, with the formation of $CuZn_5$. Here we have an irreversible reaction. The affinity of the copper and zinc is evidently much greater than that of the iron and zinc.

The action of $FeZn_{10}$ in sherardizing is not fully known. The temperature required to sherardize with this material is slightly higher than with the zinc dust and the coating always contains a higher percentage of iron than the $FeZn_{10}$, the total iron being usually from 12 to 16 per cent. In commercial practice it has been found that the $FeZn_{10}$ may be used for sherardizing purposes for a long period of time without any increase in its iron content. This would seem to indicate that the $FeZn_{10}$ is deposited as such on the iron though it is not the case with copper.

With the data presented and by a consideration of the laws of physical chemistry as applied to the formation of alloys it appears to the writer that the sherardizing action is mainly a contact action when carried out at the usual temperatures. This contact action is made possible by the formation of inter-metallic compounds. Zinc vapor may enter into the action at low temperatures but it is only at the higher temperatures, that is, near the melting point of zinc, that the vapor tension becomes high enough to enter appreciably into the reaction.

Trood[16] first explained the process as due to the porosity of the iron, the zinc vapors entering and depositing in these pores. He likened the process to the absorption of hydrogen by palladium and of ammonia by charcoal. He[17] later modified his first theory by stating that at the sherardizing temperature iron and zinc vapors are formed which produce ionic charges. Owing to the difference of potential of the ionic charges, ionic discharges occur which precipitate zinc with traces of iron. There is little evidence to support these two theories.

Effect of Iron in Coating on Its Weathering Properties

The iron in the sherardized coating has an important effect on its weathering properties. The writer has found that coatings containing high percentages of iron withstand weathering poorly.

While all of the zinc-iron alloys are electropositive to iron[18] their ability to withstand corrosion varies. The zinc-iron alloys rich in zinc, when exposed to the atmosphere, will usually turn a deep gray and finally black. At other times the surface will turn a pale yellow or red due to the oxidation of the iron in the surface alloy or in the adhering dust. This coloration will gradually become darker and turn black. This black coating is supposed to be the magnetic oxide of iron. Sherardizing which has this surface formation, becomes highly resistant to further corrosion. But this magnetic oxide is not formed in all cases.

The writer, in testing coatings containing varying percentages of iron, has usually found that those containing high percentages, above 15 to 20 per cent, are not as resistant to corrosion as those containing lower percentages. The sherardizing soon became covered with red iron oxide. Instead of turning black this oxide did not change in color and became flaky and penetrated to the iron in a short period. Such sherardizing practically afforded no protection.

The amount of iron in the zinc dust used also is important. If the zinc dust used is high in iron, 2 to 4 per cent, the dust clinging to the coating will turn red when it becomes moist. A heavy layer of iron oxide is formed immediately and this appears to penetrate to the iron base more easily. A few tenths of 1 per cent of iron in the dust will discolor the product. By keeping the zinc dust free from iron, the surface of the sherardizing cannot become colored until the iron in the coating is attacked. The coloration obtained in that manner turns to the black oxide more readily.

When the coating is high in iron the structure is more or less complex as it consists of several alloys. The potential of these alloys decreases with the increase in iron content and as a consequence the electrochemical action between the various layers results in a more rapid destruction of the coating. For this reason the sherardizing should be done so that the coating will consist of a single layer of alloy or a condition approximating that. And that result can probably only be obtained at low temperatures.

The writer has found that some manufacturers were unable to turn out as good a coating at the end of a year as when they first installed the process. When the process was new the metallic content of the zinc dust was high while the iron content was negligible. As a result a low temperature was used and a good coating was obtained. As the zinc dust was used the metallic content dropped and the iron content of the dust increased due to various causes. The temperature required for sherardizing had to be increased and as a result the coating became less resistant to weathering.

The most satisfactory results are obtained with coatings that will turn directly from the silver gray sherardizing to the deep gray and finally black magnetic ox-

[16]Trood, Samuel. Theory and Practice of Sherardizing. Iron Age, July 23, 1914.

[17]Trood, Samuel. Sherardizing. Am. Inst. of Metals, Sept., 1915.

[18]Vigoroux, E., Ducelliez, F., and Bourbon, A. Bull. Soc. Chem. Vol. II, 1912, p.480-5.

ide. While a yellow or red coloration is not harmful if it eventually turns to the black magnetic oxide, the color gives the article sherardized a rusty and poor appearance which is detrimental to its further sale. To avoid trouble, the yellow or red oxide should not be formed.

Results Obtained at the General Electric Company[19]

To obtain the best possible results in service corrosion tests, the sherardizing process has been studied in detail at the General Electric Company. By studying the process in detail the practice was standardized and a coating was obtained that gave satisfactory results under highly corrosive conditions.

It was found that in order to secure complete control of the process it was necessary to have complete temperature control and an unvarying quality of zinc dust. Electric heating was found to give the best results.

The zinc dust used consists principally of the so-called "sherardizing-zinc," a granulated zinc, with an addition of a small proportion of "blue-dust" or oxide. It contains from 80 to 92 per cent of metallic zinc. It would be impossible to run "blue-dust" with this high metallic content due to its caking. With the electric heating there is also no danger of over-heating as is the case with the gas fired or other direct fired furnace. With such a high metallic content the temperature regulation has to be close. The temperature used is about 365 deg. C.

The zinc dust is run through a magnetic separator from time to time and in this way is freed from iron. This prevents an undesirable accumulation of iron in the dust which causes an early discoloration of the coated articles.

A study of their data on sherardizing shows that the specific gravity of the coat under a certain set of conditions varies from 1 at 35 per cent of metallic zinc in the dust to 6.75 at 80 per cent. This shows that the coatings obtained under the usual sherardizing conditions are more or less porous or contain occluded oxides, etc.

The specific gravity has a decided influence on the resistance of the coating to corrosion. By means of the salt spray test it was found that only a coating with a density of at least 6.75 would stand up satisfactorily. This means that if the sherardizing is done with a dust containing less than 80 per cent the salt water spray tests will be unsatisfactory due to the porosity of the coating.

Further Corrosion Data on Sherardizing

Burgess[20] carried out an extensive investigation on sherardizing which included corrosion tests.

The sherardized coating was shown to adhere firmly to the underlying iron. In the acid corrosion tests the iron-zinc alloy was less easily attacked and therefore equal weights of hot or cold galvanizing were not as resistant.

The sherardizing coating had an average single potential of about 0.20 volt which would make it positive enough to protect iron. Burgess states: "The potential of the alloy coating is in the neighborhood of 0.20 to 0.25 volt as against 0.50 volt for pure zinc. It fulfills therefore the requirements of being electropositive to iron and it is probable that the slower rate of corrosion as compared to the more electropositive forms of zinc, is due to the fact that it is not electropositive to a wasteful degree. In the potential measurement, therefore, we see a very definite reason why a sherardized coating is more resistant to galvanic action than are other forms of zinc."

[19] General Electric Co. General Facts About Sherardizing. Bulletin Y 694, 1915.
[20] Burgess, C. F. Sherardizing Magazine, 1910.

Burgess found that the yellow appearance of the coating after exposure to the atmosphere was not harmful as it was merely the oxidation of iron in the dust clinging to the surface or the oxidation of the iron in the surface of the coating. This yellow color gradually became darker and finally turned black after which it was highly resistant to corrosion.

Leighon and Calderwood[21] carried out a series of tests on electrogalvanized and sherardized conduits and reported favorably for sherardizing.

Sherardized, cold-galvanized, and hot-galvanized fence wire erected by the American Society for Testing Materials in Pittsburgh, Pa., at the Carnegie Technical Schools were inspected by the writer in June, 1915, just previous to their removal. These had been exposed for about 6 years to the weather.

The cold-galvanized fence wire was almost completely destroyed. The hot-galvanized, which had been heavily coated without wiping after fabrication, was in good condition, except for the top row of vertical strands. All of these were covered with heavy rust. Two sherardized fences were erected. One, with a light zinc coating, was in fair condition with corroded strands in several places. The second section of sherardized fence wire, heavily coated, was in perfect condition though almost black in color. By sharply bending the wire, the coating beneath the black coloration was shown to be intact.

Tests by various investigators have shown that when the sherardizing is carried out properly the resulting coating gives excellent service under atmospheric conditions. Whether it is preferable to electro or hot galvanizing depends upon the service to which it is to be put and the material to be coated.

While it is generally true that the protection afforded an article is measured by the thickness of the zinc coating this must be modified for certain conditions. It is known that a heavy sherardized coating is brittle and will flake when bent or hammered and for this reason a heavy coat cannot be applied under all conditions.

Sherardizing properly carried out by means of granular $FeZn_6$ free from fine dust, gives the same corrosion results as the coatings obtained with zinc dust. As the articles are freer from dust, the formation of the yellow oxide is less pronounced.

Commercial Sherardizing Practice

For a detailed description of the methods used in sherardizing plants the reader is referred to the articles mentioned in footnotes 8, 15, 17, 22, 23, 24.

Following is a discussion of several important details in commercial sherardizing practice based upon data obtained by the writer while actively engaged in sherardizing practice.

Removal of Zinc Dust from Coated Articles

The problem of removing zinc dust from sherardized articles is one of the most difficult to solve as it adheres tenaciously to most surfaces. This is especially true if the surface is slightly roughened as by over-pickling. Smooth surfaces, such as are obtained on cold-rolled steel, do not allow the zinc to cling and such material is easily cleaned.

Not only is adhering dust objectionable in the further handling of the work but it also results in a more rapid deterioration of the coating by corrosive agents, as has been previously pointed out. If the articles have to be tumbled in sawdust or other similar material to remove

[21] Leighon, R. B., and Calderwood, H. A. Report of Tests on Sherardized and Electro-Galvanized Conduits. Carnegie Institute of Technology Bulletin, 1912.
[22] Liggett, T. About Sherardizing. Metal Industry, Vol. 11, p. 16.
[23] Lucas, C. F. The Practical Side of Sherardizing. Machinery, Vol. 21, 1915, p. 361.
[24] Storey, O. W. Sherardizing. Wisconsin Engineer, Vol. 16, 1912, p. 300.

the adhering zinc dust, this will usually discolor the coating. Dipping in paraffin is objectionable because of its greasy nature. Dipping in varnish is not applicable to many articles.

The problem of dust removal may be overcome to a large degree by using a high percentage of "sherardizing zinc" in the dust. It may be almost completely overcome by using granular $FeZn_7$ from which the fine dust is removed by an air separator. By using this material not only can a brilliant crystalline coating be obtained but also one that is practically free from dust.

Sherardizing of Retorts

When the process was first used, the claim was made that the interior of the retorts were not sherardized. This has not been found to be correct, the writer finding that retorts in daily use were lined with a zinc-iron alloy 1/32 to 1/16 in. in thickness. After this was once formed it became hard and adhered tenaciously, and the retorts apparently did not suffer further deterioration from this cause.

Zinc Dust Control

While temperature control of the process is essential for the best results, the percentages of metallic zinc in the zinc-dust must be kept under control. The dust should be analyzed for metallic zinc at least once a week and preferably daily. The new "blue-dust" should also be analyzed for its metallic content. The iron content of both the new and old dust should also be determined.

For the analysis of new "blue dust" the writer prefers Drewsen's Method[25]. This method depends upon the reduction of an acidified potassium dichromate solution by the finely divided zinc in the presence of sulphuric acid. Other methods[26] are the hydrogen evolution method carried out in a nitrometer with decomposing flask, reduction of potassium iodate to iodide in the presence of caustic potash, and the reduction of ferric sulphate.

For the routine analysis of used zinc dust for metallic content the hydrogen evolution method is the simplest and easiest, and gives results that are accurate enough for factory control. The amount of hydrogen evolved by dilute sulphuric or hydrochloric acid from a weighed sample is compared under prevailing temperature and pressure conditions with C. P. granulated zinc. The percentage of metallic zinc in the dust is proportional to the hydrogen evolved from the C. P. zinc.

While the hydrogen is easily evolved from used zinc dust, new dust is dissolved with difficulty due to its physical nature. A simple hydrogen evolution apparatus cannot be used with new zinc dust but can be used for old dust.

Testing of Sherardizing

While the testing of the sherardized product is required under specifications, it also serves as a check on the zinc dust and temperature used. Test pieces should be put into every retort and tested by some standard method to determine the amount of coating deposited. Although the copper sulphate or Preece method is extensively used for testing purposes, many objections have been raised to its use and other methods have been proposed.

It is well known that the copper sulphate method gives varying results with different kinds of galvanizing and that such tests are not comparable. The pure zinc coating obtained with cold galvanizing will be attacked almost twice as fast as the sherardized coating. Hot-galvanized coatings will dissolve at another rate. The bulletin of the General Electric Company[27] shows that there is even a discrepancy when sherardized coatings of varying weights are tested.

But the Preece test has a certain value. For routine factory testing the writer knows of no better method for determining the weight of the zinc deposit. Here the results are comparable, especially, where the coating does not vary by more than two or three copper sulphate dips. The writer used this method for more than two years to test the output of a 40-ton sherardizing furnace and trouble was seldom experienced. No difficulty was encountered in determining the end point as the copper always plated out brightly when the iron was exposed and was dark and loosely adherent while the sherardizing was intanct.

The results obtained by the Preece test were checked from time to time by the basic lead acetate method.[27] The latter method was used to accurately determine the weight of deposit per unit of area and also to remove the coating for analysis.

For a rapid analysis of the coating and if its weight per unit area was desired within a reasonable degree of accuracy (within 0.2 per cent) the writer devised the sulphuric acid method. This method was found to be of special value where a large number of deposits were to be investigated. The writer found that 2 per cent sulphuric acid would dissolve the coating readily without dissolving an appreciable amount of the iron base, the results being repeatedly checked by the basic lead acetate method. The loss of coating of the sherardized article was determined by weighing before and after removing the coating with 2 per cent sulphuric acid.

The specimen was removed from the acid when hydrogen practically had ceased coming off. The iron was immediately determined by titrating the solution with potassium dichromate. In this manner the weight of the coating and its percentage of iron were easily and rapidly obtained. This method would not be applicable where the iron base dissolved rapidly in cold 2 per cent sulphuric acid but with ordinary steels and irons the writer found that the iron dissolved was negligible if the specimen was removed when the zinc had dissolved.

The Preece test, basic lead acetate, sulphuric acid, and similar tests will give results which will show the thickness of deposit. While these tests do show the amount of coating they will not show the amount of protection to the iron base that the coating will give as determined by factors other than the thickness of the deposit.

Final judgment can only be given when the coatings are exposed to the atmosphere for a sufficient length of time to secure a breakdown. Even then the results obtained are for a certain set of conditions for it is obvious that different results will be obtained at the seashore, or in the coke regions of Pennsylvania than in dry climates where only a slightly corrosive atmosphere is found.

To secure results applicable to maximum corroding conditions, the General Electric Company[27] has developed the salt spray test. This test gives corrosion results in a week or two that would usually require several or more years of atmospheric exposure. This test is of much value but should be checked up from time to time by atmospheric tests.

Conclusions

1. The exact composition of the zinc-iron alloys formed in sherardizing cannot be known until the solubility relations of the two metals have been determined.

2. The coating consists of definite layers of iron-zinc compounds.

[25] Lunge, G. Technical Methods of Chemical Analysis, Vol. II, Part I, 1911, p. 299.
[26] Sutton, F. Volumetric Analysis, 1903, p. 385.
[27] Walker, W. H. Method of Testing Galvanized Iron to Replace the Preece Test. Jour. of Ind. & Eng. Chem., Vol. 3, 1911, p. 239.

3. The iron content of the sherardized coating is a function of the temperature.

4. Sherardizing is principally a contact action made possible by the formation of inter-metallic compounds.

5. Sherardizing, when carried out properly, gives a coating that is highly resistant to corrosion.

6. A zinc dust having a high metallic content will give the best coating.

7. Sherardizing should be carried out at the lowest temperature economically possible to secure a low iron content in the coating.

8. A high iron content in a sherardized coating is detrimental to its weathering properties.

9. The copper sulphate test gives excellent results for daily furnace control tests.

C. F. Burgess Laboratories, Madison, Wis.

Coke as a Reducing Agent in the Electric Smelting Furnace

BY R. C. GOSROW

The use of coke as the reducing agent in the electric smelting furnace, has been the subject of considerable argument, and some articles of literature, on the part of electrometallurgists. The experiences of several operators on this class of operations have been written up in the technical journals of the metallurgical art. Among the foremost to investigate and publish the action of coke in the electric smelting furnace in the manufacture of pig iron, were the Swedish and Norwegian metallurgists. From their experiences and data, more has been written, in the form of discussions, by American metallurgists. These data have been taken from one source and another without any verification of the statements transcribed. As a result of this practice the data existing have been recopied many times, so that I will not take space to recopy any of them, but wish to draw a few points from them, to bring out features of my discussion.

The question may be asked, "Is coke a satisfactory reducing agent, for use in the electric smelting furnace?" This question may be answered both in the positive and in the negative.

To answer in the positive, it may be stated that coke is satisfactory as a reducing agent. It contains a sufficient percentage of fixed carbon; is of sufficient crushing strength to withstand the ore column of the charge; reduces the metallic oxides to their metals; its fixed carbon is dissolved by the metal, where necessary, as in the manufacture of pig iron.

To answer in the negative, it may be stated that the carbon in coke is too dense; is somewhat refractory in the electric furnace oxidation, by the chemically combined oxygen in the ore; makes undesirable electrical conditions; causes too high electrode losses in the furnace; has the tendency to form high fusing carbides with the lime, when running on high lime slags; sows the furnace; crusts the furnace between electrodes.

These latter features are some of the factors militating against the use of coke as reducer in the electric smelting furnace. To cite more fully the conditions of the electric smelting process, in which I used coke as the reducer, I desire to state that the furnace was running on manganese ores with a high silica content; the coke carried 14 per cent ash; high sulphur content in the coke; the iron ores were pure magnetites and low in silica, but necessitated a limy slag to eliminate the high sulphur of the coke; the furnace was a three-phase furnace, with four electrodes in a straight line; the furnace was run with high charging stacks for feeding the charge; the furnace was run without the charging stacks; the furnace was run with deep crucible and high bosh; the furnace was run with shallow crucible and high bosh. This gives the general conditions attending the operations of the furnace using coke as the reducing agent.

My views and conclusions on this subject have originated from personal experiences with various ores and reducing agents in the electric smelting of iron ores and manganese ores, producing pig iron, and 80 per cent ferromanganese.

Primarily, with some diversion, it might be well to investigate the **physical and chemical properties of coke**, to endeavor to fix the property or properties which contribute to the points mentioned.

Specific Gravity: Coke per unit of volume is two-and-one-half times heavier than charcoal. It will weigh from 25 to 30 lb. per cubic foot, depending on the grade and the manufacture. This point is important in the electric smelting process.

Porosity: Coke is very porous, having a large part of its total volume made up of cell space. This property is very beneficial in the blast smelting of ores with coke. This is not so pronounced in its use in the electric furnace.

Crushing strength: Nearly all grades of coke are possessed of a crushing strength sufficient to support the ore column of the electric furnace, where short ore columns are used generally.

Volatile matter: This is usually low in cokes, not exceeding two or three per cent.

Hardness: Most metallurgical cokes are hard enough to resist abrasion in handling. This is of importance, so that the coke does not become comminuted in handling, before reaching the furnace.

Physical state of carbon: The fixed carbon in the coke is in the form of a dense, hard structure in the mass forming the walls to the cell structure. This form of the carbon is quite refractory to the process of oxidation taking place in the electric furnace. The carbon is oxidized, but not as rapidly as the carbon in charcoal, for instance. This physical form of the carbon appears to be the controlling factor for the action of coke, when used in the electric furnace.

EFFECT OF SPECIFIC GRAVITY OF COKE

From the foregoing properties of coke it is made apparent that two properties at least affect the use of coke as a reducing agent in the electric furnace. One is its specific gravity, and the other is the physical form in which its carbon is present. As regards its specific gravity, the coke which I used was not finer than 1 in. in size, from this to 1½ in. A cubic foot of this coke weighed 30 pounds (3 per cent moisture). The term specific gravity refers to the apparent specific gravity. The ratio of the coke to the ore in the charge was about 1 to 3 by weight. The ore in a single charge weighed 500 pounds and would run about 180 pounds per cubic foot. We have then approximately 2½ cu. ft. of the ore, and 5 cu. ft. of the coke. With this, in smelting iron ore for pig iron, there is a small weight of lime rock; and in smelting manganese ores for ferromanganese there is approximately 2 cu. ft. of lime rock on the charge. This latter makes the ratio of about 4½ to 5 of ore, etc., to coke, or the proportion of 1 to 1 nearly.

From this it is seen that the charge contains as much volume of material with a high resistance as it does of a material of a low resistance. In other words, the material with the high resistance takes a high voltage with a low current, and the material with the low resistance takes low voltage with high current. But it must be remembered that these materials are all mixed up in the charge, and do not occupy portions

of the furnace volume separately. So the result is a charge having a high resistance, making a high voltage necessary to overcome the resistance, with an uneconomical use of the electrical equipment.

This does not appear to be in harmony with the statements of Oedquist, brought out by J. Härden, in METALLURGICAL AND CHEMICAL ENGINEERING, February, 1914, pp. 82 et. seq. It is stated here that the conductivity of the coke is high, giving large current density and at lower voltage. This would be true providing the volume of coke in the charge would be sufficient to affect in this way the electrical conditions.

Now with charcoal the results are different. Charcoal weighs about 12½ pounds per cubic foot. For the same weight as before we would have about 13½ cu. ft. of charcoal. But charcoal is not as good a conductor as the coke is. In this case we have a ratio of ore, etc., to charcoal of 4½ to 13½, or about 1 to 3. Under these conditions, when the charcoal is heated the charge contains enough carbon to make it a conductor of the current down into the furnace, where the resistance heating is brought into effect. In the upper zones of the furnace all the material is acting as a resistance to the current. But by the downward movement of the charge this material is soon heated in its passage down into the smelting zone, and in being heated acts as a conductor for the current to the slag and the molten resistor below. In this way the temperature of the crucible is maintained at the melting temperature for the metal and slag produced.

The action of coke as a conductor, hot and cold, can be seen in starting up a furnace. The furnace was filled about 18 in. deep with coke, and the electrodes put into this about 10 in. The main furnace switch was closed, and the voltage run up to 80 volts, which was the maximum voltage used on the variable-voltage transformers.

For the first three hours the load on the furnace would not be over 50 kw. for the first hour, up to about 200 kw. at the end of the third hour. After the fourth hour the load would increase to about 600 to 800 kw. and would be maintained there for the next three or four hours. As the coke mass became incandescent it would be possible to carry 1800 to 2000 kw. in the furnace. As the load increased the voltage decreased, until it was possible to carry 1200 kw. at 45 volts. At times the load would increase so fast that the minimum voltage (40 volts) was too high to maintain the load at 1200 kw., so the main switch was pulled to allow the coke to "cool off" for two or three hours. When the switch was closed again the load would come up to 1000 to 1200 kw. at about 50 volts. This is merely to show the electrical effect in using a high percentage of coke, in this case 100 per cent.

The same effect can be produced in using charcoal, but the action is slower; the charcoal oxidizes more rapidly and is soon consumed. However, when the charcoal is incandescent it forms a good conductor for the current. Eventually as the charcoal becomes incandescent, it presents the same phenomena as with coke, low voltage, high current.

In the electric smelting furnace almost any reducing agent will present difficulties. Various factors, relative to the electrical control of the furnace, are attributed to the conductivity or resistance of the reducing agents. Considering that the cheapest and most plentiful reducing agent is some form of carboniferous material, and that carbon in various forms is a good electrical conductor when hot and less so when cold, we would have certain electrical troubles with any of the available forms of carbon for a reducing agent.

In the upper part of a furnace, where the charge is not heated even to incipient fusion, any carbon material would not be as good a conductor as it would be when reaching a higher temperature in the lower highly heated parts of the furnace. Under these conditions coke and charcoal would act practically the same as they are admixed in the charge, although the coke has a lower resistance than the charcoal. It might be the view of a polemic, but in so far as the electrical conditions are considered in the electric smelting furnace, one reducing material acts with almost the same results as another.

Most of the investigators and writers on this subject have considered the properties of coke, electrically, in the electric smelting furnace, as being the same as though no other material were admixed with it, and the coke were free to act as a conductor, unhindered by the presence of a highly insulating material, as ore and limerock, mixed throughout the coke lumps.

My previous illustration of starting a furnace on a bed of coke and heating the coke with the electric current, should be contrasted with the other starting method of mixing complete charges and charging into the crucible of the furnace, putting the electrodes into it, and "juicing in." By using the latter method, a higher voltage is necessary, with a considerably longer time to heat the charge. It shows the effect of the raw ore, etc., on the conductivity of the charge, and the masking of the conductivity of the coke. Here the size of the coke lump would be important. The larger the lumps the lower the resistance of the charge, and vice versa.

Furthermore, with the use of the coke, the method of feeding the furnace does not materially change the conditions. The coke may be fed first, and the ore charge following; it may be fed around the electrodes and the charge fed clear of the electrodes; it may be fed mixed with the charge and all fed at one time in the proper proportions for the smelting process. The ultimate electrical conditions prevail, and the metal output, and power conditions do not show any marked results that can be attributed to the change in feeding the materials.

Crawford, in his work at Heroult, says in Bulletin No. 90 of the American Institute of Mining Engineers that he used crushed coke, because with the coarse coke, the furnace made melted oxides instead of pig iron, and by crushing the same coke to 1 in. size, the furnace made normal foundry iron. The decrease in the size of the coke lump would undoubtedly make the charge somewhat denser, thus increasing its resistance. This might have made a hotter furnace, thus bringing about the more complete reduction he mentions, by making normal foundry iron. The coarse coke refers to sizes larger than 2½ in., and the fine coke refers to 1 in. to 1½ in. size.

The summary of the discussion by Härden of Oedquist's paper, referred to previously, brings out the fact that the coke has a low resistance, and does not offer enough resistance to the charge to heat the smelting zone to a sufficient temperature. It is not this lack of resistance, but in my opinion too much resistance in the charge that causes the insufficient heating. This, of course, applies to the voltages operating on, and voltages that are practicable and applicable to the electric smelting furnace.

EFFECT OF STRUCTURE

The question of the use of coke has another phase, which is a chemical one. As stated previously in this article, the carbon is in a dense hard form. In this form it is quite resistant to oxidation, unless the oxygen is forced into the cell structure and can act on the

large area of structure exposed. In the open air, coke burns with considerable difficulty.

Consider then in the electric furnace, the coke in contact with the metallic oxides, with lime, silica, alumina, magnesia, and with other of the less abundant oxides, and silicates in the ore and fluxes. As the coke is carried down in the furnace, by the downward movement of the ore column, it comes into the zone of temperature at which its carbon will react with the oxygen of the ore and form carbon monoxide, and the metal will be reduced. Also at the temperature of the arc, some carbon comes in contact with lime, alumina, magnesia, and reduces these oxides also. In this reaction the infusible carbides are formed. According to the laws of thermochemistry that reaction which takes place at the highest temperature will be the ultimate reaction. In the zone of the electric arc, in the buried arc-resistance furnace, we have the highest temperature attainable. At this temperature the ultimate reactions take place, resulting in the formation of those compounds which have the highest melting points.

To avoid further argument I have used the term "buried arc-resistance furnace" in the above paragraph. The large smelting furnace in my opinion is a combination of the buried arc with resistance heating. The arc forms from the electrode to the materials in contact with the electrode. By so heating the materials around the electrode, the incandescent mass eventually acts as a conductor from one electrode to another, and the mass of materials is then heated by resistance; the hot materials in the fused and semi-fused states being the path of the current to the other pole of the circuit.

The occurrence of the formation of carbides, I consider to be the principal objection to the use of coke in the electric smelting furnace. The formation of carbides in the furnace puts an increased duty on the furnace. The presence of such material having a high melting point soon makes the furnace run irregularly by the increased melting temperature of the material it must melt, other than that for which it was designed.

The "sowing" in the furnace is soon evidenced by the elevated bottom; temporary loss of control of the product; increased power consumption; high electrode consumption; slowing up of the rate of smelting. The accretions formed in the furnace are due to the formation of the carbides. As the carbide accumulation grows gradually, the furnace is checked in its operations, as a consequence of the heat absorption by their formation. The walls of the furnace become crusted in their lower portions. The crusting along the side walls soon forms a scaffold for the charge to hang up on, and ultimately a bridge is formed across the furnace, and holds up the entire charge above it. The material beneath the bridge will melt out, leaving the superimposed charge hanging, until eventually it will slip down. As the charge comes down, the immediate result is a broken electrode or two.

TWO DIFFERENT FURNACE DESIGNS

Now with two different types of furnace, the effect of this bridging and sowing varies with the type of furnace. In the shaft and stack type of furnace, the hanging up seems to be more marked than in the low, stackless furnace.

In the electric smelting of iron ores for the production of pig iron in the shaft and stack furnace, the hanging up in the stacks appeared to be the greatest difficulty in the operations. In this smelting the furnace was run on a high lime content in the burden to eliminate a high content of sulphur in the coke. The furnace was a covered furnace having the electrodes between the stacks, making five stacks and four electrodes. The mixed charge was dumped into the stack and the stack closed at the top, leaving only enough opening for the gases to burn freely.

With this furnace no definite knowledge was ascertained of the conditions in the furnace, other than the indirect pointers obtained from broken electrodes, and hot arches, and hanging up in stacks. It was evidenced though, that something was wrong, by the slowing up of the rate of smelting, and the slow rate at which the furnace took the charges. By "barring down" through the stacks with 16 lb. rails sometimes the bridge was broken and would fall. Other times this was no relief, and a stack was often left dead for several days, until it might open up when the furnace would work around in shape.

These bridges formed at the base of the stack, and just around the electrodes. The electrode would enter through one of these crusts through a hole about 12 in. larger than the diameter of the electrode.

Of course, this fact was not found out until after the design of the furnace had been changed, and such things could be observed and studied. With the formation of the crusts and bridges in the furnace the sow in the bottom of the furnace was forming also. This sow was not always a carbide sow, but contained considerable pig metal, which froze up as a result of being too good a conductor, when carrying current. But the cause of these conditions was primarily due to the falling off of the furnace load, as a result of the accretions and sow in the furnace.

In the other type of furnace, in which no stacks were used, and the furnace was run with an open top on manganese ores, the conditions mentioned above did not hold the same. In the absence of the high stacks, the charge had no place to hang up where it could not be got at to remedy by mechanical or hand power. The furnace was charged all over the top, and the charge was constantly stoked, to keep it from forming wall accretions, and the troublesome crusts. Whenever a sow was forming in the furnace bottom it could be known soon enough and remedied by adding oxidizing charges or by running the charge down and cutting out the sow with ore charges, or with fluorine slags. In this case the charge carried a high content of lime to make a limy slag, while running on high silica manganese ores.

It can be seen that with the two types of furnaces mentioned different results are obtained in their operations on coke. The furnace that can control the erratic and irregular conditions while using the coke reducing agent would appear to be the furnace to adopt for the smelting with coke, and with a slag that is to run at least 40 per cent to 45 per cent lime, making the burden on the furnace strongly basic.

It might be of interest to give briefly the operations attending the use of coke in the furnace of the stack type.

The coke analyzed as follows:

Proximate analysis:	Per Cent	Ash analysis:	Per Cent
Moisture	3.00	Silica	63.50
V. C. M.	3.50	Alumina	15.70
F. carbon	79.50	Lime	2.50
Ash	14.00	Magnesia	0.90
Sulphur	1.11	Sod. oxide }	5.40
Phosphorus	0.35	Pot. oxide }	
		Ferric oxide	12.30

The coke was crushed to pass a 1½-in. ring. Before going to the furnace the coke was screened over ½-in. openings in a revolving trommel. In using this coke a basic slag was carried, running about 42 per cent to 45 per cent lime. These operations were carried out on the smelting of a pure magnetite ore, producing pig iron.

During the period of these operations (about 90 days) the furnace gave incessant trouble with crusts, hang ups, broken electrodes, slipping of the charge, burned out arch roofs, cold bottom, no taps at the regular time of taps, lower silicon iron than desired, and for which the charge was calculated, and loss of lime in the furnace "somewhere." It must be understood that these troubles did not all accumulate every day, but during the run they were enough in evidence to show that the furnace was not the commercial article yet for running with coke, and that the black horse factor causing all or part of the trouble had not been brought to light.

But considering that satisfactory operations in this furnace had been conducted with charcoal as the reducer, it led me to study the coke operations and to lay the trouble to the use of coke. It would be invaluable here to give power data, and other data on these operations in more detail, but at the present writing I am not possessed of such data. The grade of iron made varied from 0.70 per cent to 3.00 per cent silicon; from 2.70 per cent to 3.50 per cent total carbon. The iron was rather high in sulphur, running from 0.023 per cent to 0.326 per cent, of course depending on the working of the furnace.

To sum up the operations, I did not consider them in any way successful operations in the type of furnace used, with the use of coke as the reducing agent, with basic limy slag.

Crawford, in the same article referred to previously, says that any grade of coke can be used by crushing it. He also says that "black butts," screenings, can be used. I do not consider any material but the cleanest to be most desirable for the electric furnace, and the process will never be established or proven successful with the use of poor materials. We used some screenings at that time, and they were the poorest material that could be found, high in ash, low in carbon, high in sulphur and phosphorus. It might be stated here that with the best coke obtainable and with the exceptionally pure magnetite ores obtainable and smelted at that time, the coke smelting might have been nearer to a commercial success. I say this from a full knowledge of the conditions referred to above, as I was actively connected with the operations.

To go further. Assume that the furnace is running normally, and an excess of carbon accumulates in the furnace. As can be readily expected, a mass of carbides will form from the excess carbon and a carbon freeze up takes place. But in the discussion on the use of coke, it is considered that the carbon being supplied by the coke is in the proper proportions to make the proper reactions take place, providing no contrary reactions hinder the former.

In the formation of carbides, another feature presents itself. The slag control is very difficult, due to the use of the lime in combining with the carbon to form calcium carbide. This molten carbide acts very corrosively on the electrodes (graphite) and increases the consumption to a prohibitive figure.

In the absence of high percentages of sulphur in the coke, high silica in the ores smelted, and the use of a slag with a low lime content, allowing the slag to run higher in silica, so as to have the slag nearly neutral or acid, it should be possible to run with coke and not have the attendant difficulties mentioned when running on a high lime burden.

This discussion is not written for the purpose of condemning the use of coke in the electric furnace. But under the conditions cited, coke does not appear to give a satisfactory, continuous, economical smelting operation.

Eventually as the supplies of timber for making charcoal will become depleted and exhausted, resort will be necessarily had to coke or some other form of carboniferous reducing agent. In order to develop this industry, and to broaden the scope of the electric smelting furnace in the production of pig iron, principally basic and foundry, the experiences of operators in published accounts will aid in developing the process and establishing the proper conditions for the electric smelting process using coke as reducer.

Los Angeles, Cal.

X-Rays and Crystal Structure with Special Reference to Certain Metals

On the occasion of the sixth annual May lecture of the (British) Institute of Metals, delivered on May 4, at a meeting of the Institute in London, Prof. **W. H. Bragg**, D.Sc., F.R.S. (Nobel Prizeman) gave an interesting account of the new method of applying the properties of X-rays to the study of crystal structure, including the structure of certain metals.

The method, it was shown by the professor, results in the determination of the exact relative positions of the atoms of which the crystal is composed. It is not successful in every case as yet because of the lack of practice and experience of the experimenters in the new field and because some of the interpretations are not fully understood. There is no lack of indications: but we are not yet fully aware of the meaning of all of them.

It is natural to attack first such crystals as have an obviously simple structure and consist of few elements associated in simple proportions. It is also of great advantage if the crystals belong to a group of isomorphous members, such as the rock salt series. This series, in fact, has everything to recommend it to the experimenter: its form is simple, that of the cube; its symmetry is high; it contains two elements only, in equal proportions, *e.g.*, sodium or potassium associated with chlorine or iodine; and there are several members of the series so that we can watch the effect of changing one element at a time. The constitution of this series was, therefore, one of the first to be examined and made plain.

The constitution of the diamond, which has also been determined, presented a rather more difficult task, because the arrangement of the atoms is not so simple as that of the rock salt series, although its form is cubic, its symmetry is high and it contains atoms of one kind only.

Of the metals which will naturally be of especial interest to the Institute of Metals, silver and copper, and by inference gold, have been shown to possess a very simple structure, in which the atoms are arranged as in the piling of shot. Bismuth and antimony have a distorted arrangement; but these two, as well as zinc, have not been completely determined. A beginning had been made with iron. The war has, however, stopped all work of the kind on this metal.

This new field of research, according to Professor Bragg, depends on a principle already known. When a regular train of waves falls upon a surface separating two media, part is reflected and part goes on. If the part that goes on meets another separating surface, a second portion is reflected and some of this emerges from the second medium in the same direction as the beam reflected from the first surface. It will happen in general that the two reflected beams are out of phase and to that extent destroy one another. Whether they do or not depends upon the relation between the wave length, the angle of the inclination of the beam to the reflecting surfaces, and the distance between the surfaces. In this way are explained the colors of the soap

film, of the thin layer of oil on the surface of a liquid, of the colors of steel when being tempered and so on.

If the reflecting surfaces are many in number, not two, the effect is made more intense and at the same time more precise. It occurs in the beautiful colors of potash crystals as shown by Lord Rayleigh. These crystals are formed of alternating layers, twinned across their surfaces of separation; and for some obscure reason the thickness of all the layers is the same though it varies from crystal to crystal. When white light containing all wave lengths is incident upon such a crystal, at a certain angle, then only that wave length is reflected for which the proper relation between the wave length, angle, and spacing holds good. If the angle is altered the wave length which is reflected is no longer the same. Hence the beautiful play of crystal colors.

It is an essential cause of success that the wave length and the spacing are not very different in amount.

We now pass on to the case of the X-rays. These consist of waves—so indeed these very experiments tell us—which are something like 10,000 times shorter than the wave length of light. To obtain the parallel effect we must look for reflecting surfaces which are 10,000 times closer together than the twinning surfaces of the chlorate of potash crystals, and these are separated from one another by only the 40/1000 of an inch or thereabout. These also Nature has provided in the layers of atoms in the crystal.

It may seem curious that a layer of atoms should act as a reflecting surface; but after all it is not necessary that such a surface should be continuous. A row of iron railings, for example, can act as a reflector of sound waves. A natural face of a crystal contains no doubt a layer of atoms arranged regularly; and behind the natural face are other layers all similar, and placed at regularly increasing distances behind it. Thus all the conditions for this peculiar reflection experiment are present, and we actually find that when a pencil of X-rays of a definite wave length are allowed to fall upon the face of the crystal, and the crystal is gradually turned round so as to alter the angle of incidence, the reflection of the beam as a whole is non-existent except when the angle is right. Then it flashes out strongly. When this angle is observed, the relation of the wave length to the spacing is known.

The instrument used is called the X-ray spectrometer. It has no lenses because X-rays cannot be refracted; and the rays are invisible so that in place of the telescope appears a chamber containing gas which is ionized by the X-rays. The resulting electrical effect is observed in an electroscope. It is important that the measurement of the result is quantitative so that in this respect the new spectrometer has an advantage over the old.

In this way if we use always the same X-ray we can compare the spacings between the layers parallel to one after another of the natural faces parallel to the crystal; and in this way we arrive finally at the crystal structure. The instrument is not at all difficult to use, and the observed effects are large and precise so that it is quite easy to get numerical results. The interpretation is not always quite so easy. One part of it comes readily, viz: the number of molecules to each unit of the pattern of the crystal—the unit being the smaller part which being reflected again and again without alteration or orientation or distance from its neighbors forms the complete crystal. For instance, the unit of pattern of potassium sulphate contains four molecules: the unit of pattern of antimony contains two atoms.

The far greater difficulty lies in the determination of the way in which the atoms are arranged in the unit. These data are sufficient, but the interpretation is hard.

The Distribution of Silver Between Metallic Lead and Litharge-Containing Slags

BY BOYD DUDLEY, JR.

(*Concluded from page* 641)

The Effect of Litharge

The positions of the curves in Fig. 3 indicate that for a given temperature there is a close and consistent relationship between the percentage of litharge in the slag and the ratio of equilibrium concentrations. As the percentage of litharge increases the concentration ratio decreases, indicating that the power of the slag to retain silver in the presence of metallic lead increases with increasing litharge content. This is in agreement with the prevailing idea that high litharge slags retain more silver than do low litharge slags. To so state the proposition is qualitatively correct, but the data at hand provide further information and show that the dissolving power of the slag for silver is almost, if not entirely, due to its litharge content.

In connection with the foregoing it seems advisable to particularly emphasize the fact that all data herein presented are in terms of unit quantities of slag and metal. The logical way in which to view the question of slag losses is with reference to the amount of slag as compared with the amount of lead. If two assays are made on equal quantities of an ore with slags of the same composition and with the same amounts of lead reduced in each, but with twice as much slag in one as in the other, it seems obvious that, under given temperature conditions, the total silver retained by the first slag will be approximately twice that retained by the second. However, in spite of the self-evident nature of this proposition the effect of quantity of slag upon slag losses in assaying has been quite generally disregarded by writers on this subject. When it is thoroughly understood that a true chemical equilibrium is involved, it becomes clear that the total quantity of silver retained by the slag will be proportional to the quantity of slag produced, other conditions being constant.

To bring out most clearly the effect of various percentages of litharge upon the ability of the slag to retain silver it is necessary to calculate the molecular percentages of litharge in the various slags, and to compare these with the reciprocals of the equilibrium concentration ratios. The importance of the litharge content is evident from Fig. 3, but its effect upon the retention of silver by the slag is not proportional to the percentage of litharge by weight. A brief consideration of this point will show that such a rela-

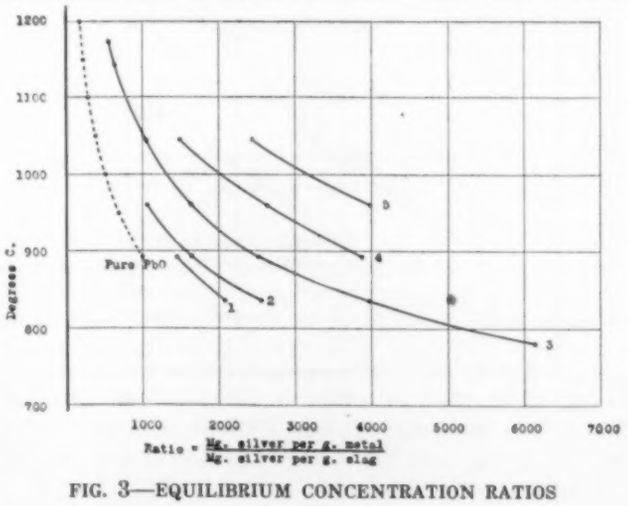

FIG. 3—EQUILIBRIUM CONCENTRATION RATIOS

tionship is not necessarily to be expected, because whatever effect the litharge may exert in the way of dissolving silver will probably be produced by molecules of litharge and not by grams of this material. Consequently, the concentration of the molecules of litharge in the slag with reference to the other molecular species that may be present, rather than the weight percentage of the litharge, is to be considered.

The concentration ratios given in the preceding tables and plotted in Fig. 3 are measures of the ability of the slags to retain silver, but their reciprocals provide a more direct measure. The reciprocal of the concentration ratio represents the concentration of the silver in the slag when its concentration in the metal, with which the slag is in contact, is unity. The reciprocal provides, therefore, a direct measure of the dissolving power of the slag for silver in the presence of metallic lead.

Table VII has been constructed to show the relation of the molecular percentage of litharge to the dissolving power of the slag for silver. In it the reciprocals of the concentration ratios have been multiplied by 10,000 in order to avoid the use of very small fractions. The molecular percentages of the litharge were calculated from the analyses of the slags shown in Table II by the customary method.

Table VII.—Reciprocals of Concentration Ratios × 10,000 in Relation to Temperature and Molecular Percentage of Litharge

Slag No.	Weight, Per Cent PbO	Molecular, Per Cent PbO	Reciprocals of Concentration Ratios × 10,000 837°	892°	960°	1045°	1143°	1173° C.
1	89.7	71.1	4.81	6.90	...	...	....	....
2	85.0	61.7	3.92	6.16	9.44	...	....	....
3	71.7	41.4	2.52	3.98	6.10	9.53	16.00	17.90
4	48.3	20.4	...	2.58	3.80	6.71	....	....
5	24.9	8.4	...	...	2.50	4.12	....	....

Fig. 4 shows the data of Table VII plotted to scale with molecular percentages of litharge as abscissas and reciprocals of concentration ratios multiplied by 10,000 as ordinates. It is seen that, within the limits of experimental error, the ability of the slag to retain silver in the presence of metallic lead is found to be a direct function of the molecular concentration of the litharge present. It appears that with no litharge present in the slag, i.e., with a slag composed of silica, boric oxide, and soda, the amount of silver retained would be comparatively little, though as to the exact amount under such conditions the data are inconclusive.

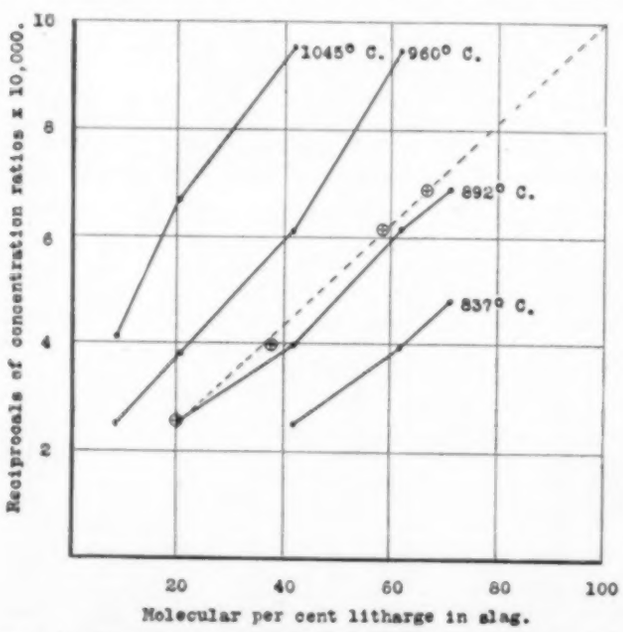

FIG. 4—RECIPROCALS OF SILVER CONCENTRATION RATIOS X 10,000 PLOTTED AGAINST MOLECULAR CONCENTRATIONS OF LITHARGE IN THE SLAGS

The most important point shown by Fig. 4 is that at constant temperature the ability of such slags to dissolve and to retain silver is mainly dependent upon the molecular concentration of the litharge, and is independent of the so-called silicate degree or oxygen ratio of the slag. It will be noted that slags are represented that vary in oxygen ratio from 0.48 to 1.71, but that such variations fail to make themselves apparent. The obvious conclusion is that the molecule of litharge in igneous fusion with other molecules retains its specific properties to a sufficient extent to exert the same solution effect upon silver, whether it is associated with few or many molecules of other kinds. In other words, such slags may perhaps be better regarded as simple solutions of various oxides dissolved in each other than as solutions of associated compounds that might be formed by the combination of these oxides.

In considering the data presented in Table VII and in Fig. 4, it is necessary to bear in mind that the litharge concentrations specified are calculated from the original constituents added to the crucible charge. It has been previously noted that the slags resulting from these fusions contain less litharge than the calculations would indicate. This is largely on account of the dilution of the slag caused by corrosion of the crucible and stirrer while the slag is in contact with them. In general, the departure of the litharge content of the slag obtained from the calculated figure increases with increasing temperature and with increasing litharge concentration in the slag. Consequently, it can be said that the positions of straight lines drawn in Fig. 4 to show the effect of litharge concentration upon silver retained at various temperatures should be somewhat higher and have a greater slope than those shown. However, the lines that are shown are perhaps as useful in regard to practical conditions as would be those occupying the precisely correct positions, because the ones shown actually represent results secured when certain charges are compounded and fused in clay crucibles, thus allowing for the dilution of the slag that necessarily accompanies this most customary procedure.

Losses of Silver in Cupellation

On the other hand, if the true litharge content of the slag at the end of the experiment is known, the relationship shown by Fig. 4 will provide a fairly accurate means of estimating by extrapolation the ability of pure litharge to retain silver in the presence of metallic lead. Such information is of much interest in connection with the subject of cupellation. Whether the process is being employed for determinative purposes, or for the purpose of separating silver from lead on a large scale, the litharge produced by the oxidation of the lead is formed as a fairly thin film over the surface of the molten alloy undergoing cupellation. Owing to the comparative thinness of the litharge film, to its fluidity, and to its movement over the surface of the molten alloy, the litharge has an excellent opportunity to dissolve that amount of silver which it is able to retain under the existing conditions of alloy composition and temperature. In other words, the chances for establishing equilibrium between the litharge and the metal are good. This is probably particularly true of cupellation on a small scale for determinative purposes, the film of litharge under these conditions being extremely thin.

The litharge formed at any instant flows from the surface of the metal and carries with it the silver that it has dissolved, the concentration of silver in the

litharge being dependent upon its concentration in the metal and upon the temperature at the surface of the metal where the oxidation occurs. As the concentration of the silver in the metal increases its concentration in the litharge will increase, hence the loss of silver will be greater toward the finish of the cupellation. Of course, the loss of silver due to its solution in the litharge is not the only loss occurring during cupellation. Unquestionably some silver is removed from the cupel by volatilization, and probably some of the silver-lead alloy is absorbed as such by the cupel. But the loss due to the dissolving power of the litharge for silver is in most cases fully as important as are all of the others taken together. Therefore, a study of the available information in regard to the nature and magnitude of this loss appears to be worth while.

Dissolving Power of Pure Litharge

The importance of determining the actual litharge content of the slag at the conclusion of each experiment was, unfortunately, not recognized at the time the work was done, and samples of the slags were not saved. It was not foreseen that the results of experiments with litharge-containing slags could be extended to yield information concerning the properties of pure litharge. In order to determine the approximate compositions of the slags actually produced from the crucible charges, a number of fusions of slags 1, 2, 3 and 4 were made in duplicate at 892 deg. C. The charges were prepared, fused, held at constant temperature, and stirred for the same time and in the same way as was the case during the previous experiments. The slags were then analyzed for lead. By assuming the variation of the litharge content of the slag as actually produced from its calculated composition to be caused by dilution of the slag with clay from the crucible and stirrer, the approximate molecular composition of the slag secured can be calculated. The clay dissolved consisted of silica and alumina in almost equal parts, hence the average molecular weight of the diluent is approximately 80. The increase in weight of the slag corresponding to the difference between the calculated litharge content of the slag and that actually observed is therefore produced by dilution with substances having this average molecular weight. From the analyses of the slags as obtained, and from the compositions calculated from the reagents employed, the molecular percentages of litharge in the slags produced can be calculated by the usual methods.

Table VIII shows the results of analyses and the molecular percentages of litharge in the slags actually produced. Averages of two analyses are given for each slag.

TABLE VIII.—MOLECULAR PERCENTAGES OF LITHARGE IN SLAGS PRODUCED AT 892 C.

Slag No.	Calculated Wt., Per Cent PbO	Obtained Wt., Per Cent PbO	Dilution by Clay, Wt., Per Cent	Calculated Mol., Per Cent PbO	Obtained Mol., Per Cent PbO
1	89.7	87.1	3.0	71.7	66.7
2	85.0	82.7	2.8	61.7	58.4
3	71.7	68.9	4.1	41.4	37.6
4	48.3	47.9	1.0	20.4	20.2

The greatest dilution was experienced by slag No. 3, which is both less basic and contains less litharge than slags No. 1 and No. 2. The reason for this is that the time during which No. 3 was in contact with the crucible and stirrer was nearly two hours, while No. 1 and No. 2 were in the furnace only about one hour.

The molecular percentages of litharge in the slags as they were actually obtained have been plotted in Fig. 4 against their corresponding reciprocals of concentration ratios. The dotted straight line drawn through these points represents the true relationship between the ability of the slag to dissolve and to retain silver in the presence of metallic lead and the molecular concentration of litharge in the slag. This line represents the conditions at 892 deg. C. By extending it to the line on the diagram representing 100 molecular per cent of litharge, the probable dissolving power of the pure material for silver at this temperature will be obtained. The point of intersection of the dotted line with the 100 per cent litharge line is approximately 10, as measured by the scale of the axis of ordinates. Since the ordinates in this figure are the reciprocals of concentration ratios multiplied by 10,000, the ratio of the equilibrium concentrations of silver in lead and in pure litharge at 892 deg. C. is found to be

$$\frac{1}{10} \times 10{,}000 = 1000.$$

That is, with lead and pure litharge in contact at 892 deg. C., and with silver distributed between them, the concentration of silver in the metal will be 1000 times as great as its concentration in the litharge, unit weights being considered in each case.

Equilibrium with Rich Silver-Lead Alloys

All of the concentration ratios that have been previously presented are in terms of mg. of silver per g. of metal divided by mg. of silver per g. of slag. If weight percentages were employed the results would be the same. Such ratios will correctly represent equilibrium conditions so long as the concentration of silver in the metal remains below about 10 per cent by weight, Such high concentrations are, of course, not ordinarily encountered in the crucible fusion, so for purposes of indicating the magnitude of slag losses in this process the figures given are entirely sufficient. But in extending the results to cover the case of pure litharge, and to indicate the loss of silver during cupellation, the question naturally arises as to what the equilibrium conditions are when litharge is in contact with silver-lead alloys of greater richness than 10 per cent silver by weight.

In order to determine this point a series of experiments was performed, in which slag No. 3 was held in contact at 837 deg. C. with alloys containing 30, 50 and 70 per cent of silver by weight. The method of procedure was the same as has been previously described. The results of these experiments are set forth in Table IX, in which the first line of figures relating to a 5-per cent silver alloy represents the average results previously secured with slag No. 3, and detailed in Table IV.

TABLE IX.—RESULTS WITH SLAG NO. 3 AND RICH SILVER-LEAD ALLOYS AT 837° C.

a Wt. Per Cent Silver in Alloy After Experiment	b Mol. Per Cent Silver in Alloy After Experiment	c Mg. Silver per g. slag	d Ratio c/d
5.0	9.2	0.0126	730
30.1	45.3	0.0592	765
29.9	45.0	0.0610	737
50.8	66.4	0.0923	720
50.1	65.8	0.0845	779
70.1	81.8	0.109	750
69.9	81.6	0.115	710

Note: The fusions were made in pairs, and in each case the equilibrium was approached from both sides. The slag assays given under "c" are corrected values, checks having been used with the cupellations.

When the weight percentages of silver in the alloy are considered in connection with the concentrations of silver in the slag, there is no apparent relationship. But when these weight percentages are calculated to molecular percentages, assuming that both metals are present in the alloy in the monatomic state, and divided by their corresponding concentrations of silver in the slag, a series of practically constant ratios is obtained. The variations between these ratios are not greater than might be expected, when the different sources of experimental errors are considered.

The results of experiments with the rich silver-lead alloys show that the equilibrium concentration of silver in the slag is directly proportional to the molecular concentration of silver in the metal rather than to the weight percentage of silver therein. This conclusion does not conflict with the results shown in Table IV, where it was seen that, between the limits of 2 per cent and 8 per cent of silver in the metal by weight, the equilibrium concentration of silver in the slag is directly proportional to the weight percentage of silver in the alloy. Simple calculations show that within these limits the ratio between the composition of the alloy by weight and its molecular composition is so nearly constant that the variation could not be detected by the methods of experiment employed. But when the concentration of silver in the alloy is increased beyond about 10 per cent by weight, the ratio between the weight percentage and the molecular percentage is altered to such an extent that the variation becomes apparent. It is unnecessary in any case to convert the silver concentration in the slag to terms of molecular concentration, because in all cases the slag is very dilute with respect to silver.

General Statement of Equilibrium Conditions

All of the foregoing facts and figures can be summed up in a single statement as follows: At a given temperature the equilibrium concentration of silver in a slag of the type that has been investigated is directly proportional to the molecular concentration of silver in the metal with which the slag is in contact, and it is also directly proportional to the molecular concentration of litharge in the slag. Expressed in the form of an equation this statement appears thus

$$\frac{\text{Mol. per cent silver in metal}}{\text{Mg. silver per g. slag}} = \frac{\text{Constant}}{\text{Mol. per cent litharge in slag}}$$

In the case of a given slag the molecular percentage of litharge is itself a constant, and, if the concentration of silver in the metal is not too great, the molecular percentage of silver in the metal will be proportional to the weight percentage. Under such conditions the above equation may be reduced to the form

$$\frac{\text{Mg. of silver per g. metal}}{\text{Mg. of silver per g. slag}} = K \text{ (a constant)},$$

which is the relationship originally determined and expressed in Tables IV, V, and VI.

In just what form the silver is present in the slag, and by what reaction its dissolution in the litharge is effected are points that at present cannot be definitely settled. It appears that the litharge is the most active of the slag-forming constituents employed in point of ability to dissolve silver. In fact, the other oxides entering into the constitution of the slags under consideration seem to have practically no power to dissolve silver and to retain it in the presence of metallic lead. From the relationship deduced in the preceding paragraph it might be said that the litharge possesses the ability to dissolve a definite quantity, expressed in molecular weights, of the silver-lead alloy with which it is in contact, and that this ability is independent of the degree to which the litharge may be diluted by other molecular species. If such is actually the case, then the observed variations of silver concentration in the slag with changing silver concentration in the metal and with changing litharge concentration in the slag are accounted for. On the other hand, the experimental results appear in many respects to indicate that the silver is dissolved by the litharge or slag in the form of silver oxide, which may be produced by a reversible reaction represented by the following equation:

$$2Ag + PbO = Ag_2O + Pb$$

Supporting this theory is the fact that the litharge is the only readily reducible oxide present in the slag, and, therefore, the amount of silver oxidized and retained by the slag will depend mainly upon the amount of litharge present. Opposed to it is the experimental work of Lewis,[3] who has shown that silver oxide is a very unstable compound at elevated temperatures, it having a strong tendency to dissociate into metallic silver and oxygen. The dissociation tensions were found to be as follows:

Temperature, C.	Dissociation Tension in Atmospheres of Oxygen
302	20.5
325	32.0
445	207.

It is evident that the tendency of pure silver oxide to dissociate into metallic silver and oxygen at the temperature of the assay furnace would be measured in terms of thousands of atmospheres of oxygen. But it is entirely possible that the dissociation tension of this compound may be greatly depressed when it is present in very dilute form in a slag.

Which of the two proposed theories offers the correct explanation of the ability of the slags to retain silver the writer is not prepared to state. The experimental results point in part to each, and it may be that the litharge both dissolves a portion of the alloy as such and at the same time oxidizes a portion of the silver. Whatever may be the true explanation, the effect is found to be the same as might be predicted from the hypothesis that the litharge simply dissolves a portion of the alloy with which it is in contact.

Effect of Temperature on Dissolving Power of Litharge

It has already been shown that the probable ratio of equilibrium concentrations of silver in a dilute silver-lead alloy and in pure litharge at 892 deg. C. is 1000, concentrations by weight being considered. Several methods are available whereby this information may be extended to other temperatures. Probably the best way is to start from the point mentioned and construct a curve similar to those representing the various slags in Fig. 3. The necessary calculations for the construction of such a curve may be made with the aid of the van't Hoff equation,[3] which is:

$$\frac{d \log_e K}{dT} = \frac{Q}{RT^2}$$

In this equation K is, in general, a mass action constant, which in the case under consideration is represented by the ratio of equilibrium concentrations of silver in the metal and in the slag; Q is the heat of reaction of the process as it takes place at the absolute temperature represented by T. More exactly, Q is the heat evolved by the reaction when a molecule of the reactant represented in the denominator of K is produced. If it is assumed that the litharge simply dissolves the alloy, then Q represents the heat of solution. The quantity R is the constant of the gas laws; its value is 1.985 g. calories.

The above is a differential equation, the integral of which is

$$\log_e K = -\frac{Q}{RT} + B,$$

where B is the constant of integration. If the values of K are K_1 and K_2 at the temperatures T_1 and T_2 re-

[3] *Journal Am. Chem. Soc.*, XXVIII, part 1, p. 139 (1906).
[3] Nernst, Theoretical Chemistry, Trans. 6th Ger. Ed., p. 654.

spectively, by substitution the two following equations are obtained:

$$\log_e K_1 = -\frac{Q}{RT_1} + B,$$

$$\log_e K_2 = -\frac{Q}{RT_2} + B.$$

Subtraction of the first of these from the second gives

$$\log_e K_2 - \log_e K_1 = \frac{Q(T_2 - T_1)}{RT_1T_2}$$

Substituting for R its value, 1.985 cal., and employing logarithms to the base 10, produces the working equations,

$$\log K_2 - \log K_1 = \frac{Q}{4.571} \cdot \frac{(T_2 - T_1)}{(T_1T_2)}$$

and

$$Q = \frac{4.571(\log K_2 - \log K_1)(T_1T_2)}{T_2 - T_1}.$$

In the above integration it is assumed that Q is independent of the temperature, which is not generally the case. But the experiments under consideration were not sufficiently exact to indicate the variations of Q with temperature, so the assumption that it does not vary is consistent with the general precision of the results.

By means of the integrated equation and the values of K for various temperatures a number of values of Q can be calculated, the average of which will provide a fairly correct average value for the heat-of-solution of silver in the slags over the range of temperature covered by the experiments. The method of calculation is illustrated by the following example. Experiments with slag No. 3 at 780 deg. and 837 deg. C. (1053 deg. and 1110 deg. absolute) show the equilibrium concentration ratios of silver in the metal and in the slag to be 6140 and 3980 respectively. The following substitutions in the integrated van't Hoff equation will yield the value of Q corresponding to these data:

$$T_1 = 1053$$
$$T_2 = 1110$$
$$K_1 = 6140$$
$$K_2 = 3980$$
$$\log K_1 = 3.7882$$
$$\log K_2 = 3.6000$$

$$\frac{4.571(3.6000 - 3.7882)1053 \times 1110Q}{57} = -17{,}700 \text{ cal.}$$

Similar calculations have been made with the aid of all data contained in Tables IV, V, and VI. The resulting values of Q are collected in Table X.

TABLE X.—CALCULATED VALUES OF Q FOR ALL SLAGS AND TEMPERATURE RANGES

Slag No.	Temperature Range, C.	Calculated Value of Q
1	837 to 892	—16,800
2	837 to 892	—20,900
2	892 to 960	—18,200
3	780 to 837	—17,700
3	837 to 892	—21,500
3	892 to 960	—17,800
3	960 to 1045	—16,900
3	1045 to 1143	—19,500
3	1143 to 1173	—15,400
4	892 to 960	—16,400
4	960 to 1045	—21,600
5	960 to 1045	—18,900
	Average value of Q =	—18,500 cal.

The fact that no consistent relationship between the heat of reaction and the composition of the slags is disclosed by the twelve values of Q thus obtained constitutes additional proof of the proposition that the same reaction, whatever its nature may be, is responsible in each case for the transfer of silver from the metal to the slag, or the reverse. Therefore, it appears safe to assume that the figure —18,500, representing the average heat-of-reaction found in Table X, will apply when the slag consists of pure litharge as well as when it is a solution of litharge in other oxides. With the aid of this assumption the equilibrium concentration ratio at any temperature of silver in silver-lead alloys and pure litharge may be calculated from the previously obtained value of 1000 at 892 deg. C. See Fig. 4.

For example, to calculate the concentration ratio at 950 deg. C. for silver in dilute silver-lead alloys and pure litharge, the following substitutions are made in the integrated van't Hoff equation:

$$\log K_1 = \log 1000 = 3.0000$$
$$T_1 = 892 + 273 = 1165$$
$$T_2 = 950 + 273 = 1223$$
$$Q = -18{,}500$$

$$\log K_2 - 3.0000 = -\frac{-18{,}500(1223 - 1165)}{4.571 \times 1165 \times 1223}$$

$$\log K_2 = 3.0000 - 0.1646 = 2.8354$$
$$K_2 = K_{950\ deg.} = 685.$$

Similar calculations have been made for temperatures above 950 deg. with results as shown in Table XI. The calculated values are plotted to scale in Fig. 3 with a dotted line drawn through the points.

TABLE XI.—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN DILUTE SILVER-LEAD ALLOYS AND PURE LITHARGE AT VARIOUS TEMPERATURES

Temperature, C.	Ratio = Mg. of silver per g. of metal / Mg. of silver per g. of litharge
892	1000
950	685
1000	507
1050	385
1100	298
1150	235
1200	188

The concentration ratios thus obtained represent with fair accuracy the equilibrium conditions so long as the concentration of silver in the metal remains below about 10 per cent. Above this point another set of values is required, because the concentration of silver in the litharge is in reality proportional to its molecular concentration in the metal rather than to its weight concentration therein. Accordingly, a set of ratios has been calculated which represents the relationship between the molecular percentage of silver in the metal and the mg. of silver per g. of slag at various temperatures. In order to calculate such a ratio assume a concentration of silver in the metal equivalent to 40 mg. per g., or 4 per cent by weight. This corresponds very closely to the composition of the alloys employed in most of the slag experiments. The molecular percentage of silver equivalent to this weight percentage is 7.40. From Fig. 3 it is seen that at 900 deg. C. the ratio of equilibrium concentration of silver in the metal and silver in pure litharge is 950, weight concentration being considered. The corresponding concentration of silver in the litharge will be

$$\frac{40}{950} = 0.0421 \text{ mg. of silver per g. of litharge.}$$

The desired ratio of molecular percentage of silver in the alloy to concentration of silver in the litharge may now be obtained by division,

$$\frac{7.40}{0.0421} = 176.$$

Ratios corresponding to other temperatures have been calculated. The resulting values are given in Table XII, and are shown plotted to scale against their corresponding temperatures in Fig. 5.

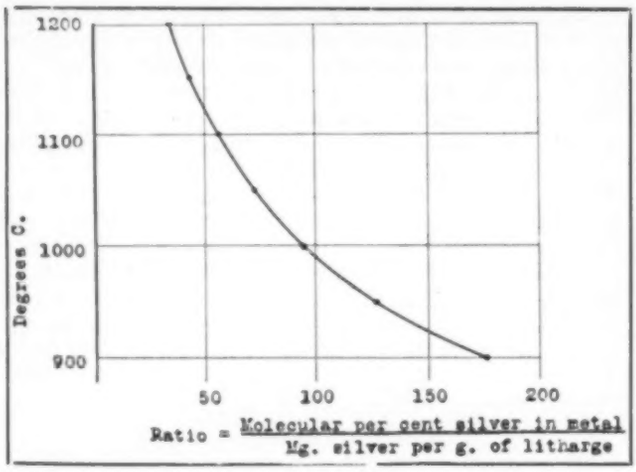

FIG. 5—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN SILVER LEAD ALLOYS AND PURE LITHARGE AT VARIOUS TEMPERATURES

To facilitate the use of Table XII Fig. 6 is provided, which shows the relation between molecular and weight percentage in silver-lead alloys.

The ratios of molecular per cent of silver in the metal to mg. of silver per g. of litharge may apparently be relied upon to indicate with reasonable accuracy the equilibrium conditions at various temperatures when pure litharge is held in contact with silver-lead alloys

TABLE XII.—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN SILVER-LEAD ALLOYS AND PURE LITHARGE AT VARIOUS TEMPERATURES

Temperature, C.	Ratio = Molecular per cent silver in metal / Mg. of silver per g. of litharge
900	176
950	127
1000	94
1050	69.5
1100	55.2
1150	43.6
1200	34.8

of compositions up to 70 per cent silver by weight. Experimental work with the slags has not been carried beyond this point. Therefore, positive evidence in regard to more concentrated alloys is lacking. But various records of cupellation in the English type of cupelling furnace show that the concentration of silver in litharge from rich bullion is generally much higher than the ratios of Table XII would indicate. However, in comparing these ratios with any figures from practice it should be remembered that they are supposed to indicate the concentration of silver actually dissolved in pure litharge, when equilibrium has been established between it and the metal with which it is in contact.

The litharge made in the cupellation furnace is generally not pure, but contains oxides of other metals in various amounts. These oxides may exert a greater dissolving action upon the silver than would an equal amount of pure litharge, and owing to this fact the dissolved silver in furnace litharge may be higher than the above equilibrium ratios would indicate. A part of the silver contained in cupel furnace litharge is almost invariably present as minute shots of the silver-lead alloy mechanically carried, and some of the high assay values of furnace litharges are doubtless due to this fact. These points should be taken into consideration when the equilibrium ratios of Table XII are compared with data from practice.

In addition to the above reasons why furnace litharge may be much richer in silver than the concentrations corresponding to the ratios in question, there is another possible explanation, which should not be overlooked. If all or a considerable part of the silver is held by the slag or litharge in the form of silver oxide, then it is entirely possible that, when a rich silver-lead alloy is subjected to rapid oxidation, the litharge as it is first formed may contain a much greater amount of silver than corresponds to the equilibrium concentration. If there is intimate contact between the metal and the litharge for a sufficient length of time, the excess of oxidized silver will re-enter the metal. But under conditions of rapid cupellation and rapid removal of litharge from the metal this condition of supersaturation may not be relieved. Hence, if the silver is actually subject to oxidation to any considerable extent, the litharge produced may contain much more dissolved silver than corresponds to equilibrium conditions. It would appear that in the ordinary laboratory cupellation for determinative purposes, where oxidation is comparatively slow and the litharge is formed as an exceedingly thin film over the surface of the alloy, the conditions would be quite favorable to the attainment of equilibrium between the litharge and the metal. While in furnace cupellation on a large scale where rapid oxidation with forced draft is the rule, the conditions are not so favorable to the attainment of the equilibrium conditions that correspond to the temperature at which the operation is conducted.

Much more experimental work is necessary before the physical chemistry of cupellation can be thoroughly understood. In this paper an attempt has been made, by extending the data secured from experiments with litharge-containing slags, to provide a little information, which appears to be reasonably accurate so far as it goes. That it does not go far enough to settle all of the questions involved is quite evident. But it appears that further work should involve experiments with pure litharge rather than with more or less concentrated litharge slags, and on this account work with the slags has been discontinued. In this connection it may be well to note that the principal difficulty encountered in attempts to study pure litharge lies in securing a proper container for the molten material. Dilution and reduction of the litharge have to be avoided, and molten litharge is almost as fluid as water. Consequently, if the properties of pure litharge are to be studied, the container must be chemically inert to the action of the molten material at high temperatures, and it must be relatively dense and non-porous.

It is because of the difficulties encountered in pro-

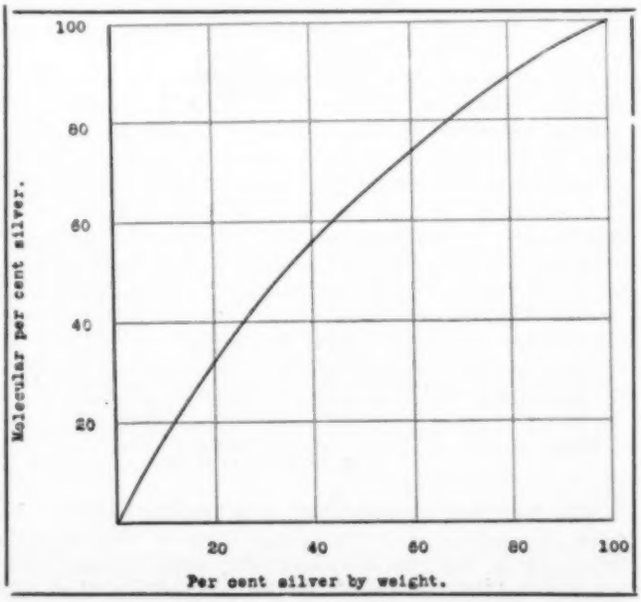

FIG. 6—WEIGHT PERCENTAGES AND MOLECULAR PERCENTAGES OF SILVER IN SILVER-LEAD ALLOYS

curing such an ideal container that the experiments have not been carried further in this direction. It is on this account also that the temptation to extrapolate the results of the slag experiments to the point where the properties of pure litharge are indicated has proved irresistible. The only straw in sight has been grasped; whether the results thereby secured will be shown by actual experiment to be good or otherwise remains to be seen.

Summary

The results of the experimental work recorded above may be summarized as follows:

1. Slags consisting of PbO, Na_2O, SiO_2, and B_2O_3 retain silver in the presence of metallic lead, a true state of equilibrium between the metal and the slag being attainable under each set of conditions.

2. The total amount of silver retained by the slag is proportional to the weight of the slag. Hence, under definite conditions a definite concentration of silver in the slag is required to produce equilibrium.

3. The concentration of silver in the slag increases with increasing temperature, other conditions being constant. The rate of increase of the silver concentration is somewhat greater than the rate of temperature increase. See Fig. 4.

4. At constant temperature the concentration of silver in the slag varies directly with its concentration in the alloy, with which the slag is in contact.

5. For small concentrations of silver in the metal its concentration in the slag is proportional to its weight percentage in the alloy. With richer silver-lead alloys the silver concentration in the slag is found to be proportional to the molecular percentage of silver in the metal.

6. Litharge is found to be the most active of the slag-forming constituents in point of ability to dissolve and retain silver.

7. Other conditions being constant, the amount of silver retained by the slag is directly proportional to the molecular concentration of litharge in the slag, and is independent of the silicate degree or oxygen ratio of the slag.

8. An extention of the data secured from experiments with the slags yields provisional information in regard to the ability of pure litharge to dissolve and retain silver in the presence of metallic lead.

9. The results are inconclusive in regard to the condition or state in which silver is held in solution by litharge. While in all cases studied the resulting concentration of silver in the slag was found to be what might be expected if the litharge actually dissolves a portion of the alloy with which it is in contact, this fact in no way precludes the possibility of the silver being oxidized to a greater or less extent.

Note.—In the first part of this article published in the issue of June 1, on page 640 in the second column the paragraph beginning "All experiments performed, etc.," is misplaced. It should appear immediately before the paragraph on page 641 in the second column that begins "The average ratios, etc."

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The Kalbfleisch Chemical Corporation will build a new chemical plant at Chattanooga, Tenn., to cost about $75,000.

The West Virginia Pulp & Paper Company at Mechanicville, N. Y., is installing additional capacity in connection with its alcohol plant. A large Swenson quadruple effect evaporator is being completed for this plant at Chicago and it is expected that this will be erected in a very short while.

Wood Waste and Other Pulpwoods Used in 1914 by United States Mills

BY HENRY E. SURFACE

Engineer in Forest Products, Forest Products Laboratory.

In the latter part of the year 1915, the Forest Products Laboratory was in need of immediate current data in connection with a study of the progress being made in the utilization of wood waste as pulpwood, and since no recent statistics were available from other sources, a questionnaire in this regard was sent out to the various consuming establishments. A summary of the statistics obtained, together with a brief discussion of an incidental consideration brought out by the apparently decreased consumption and the high price being paid for pulpwood by many of the mills is given below as of public interest, although the concerns so kindly co-operating in the study have already received certain advance information.

The 1914 figures of pulpwood consumption given herein must be considered more in the nature of estimates than as formal statistics. The latest official data on the wood and wood waste used in the United States for the production of paper pulp, that are at present available to the public, are those covering the year 1911 as published by the Bureau of Census, U. S. Department of Commerce, in its circular entitled "Forest Products No. 1; Pulpwood Consumption: 1911." Similar official statistics had been prepared in co-operation with the Forest Service, U. S. Department of Agriculture each year since 1905 but they were discontinued in 1911, and under the existing plan the only sources of such information will be the decennial and quinquennial censuses. The most recent of these, namely, the "Census of Manufactures: 1914" covered the pulpwoods used in that year, but the rather comprehensive data collected will probably not be in shape for publication until late in 1916. When these figures become available it will be interesting to observe in comparison those given below, since both cover the calendar year 1914. In doing so, it should be remembered that this present inquiry was made for a special purpose entirely foreign to the usual census needs. It did not cover so great a field, and absolute statistical accuracy was not essential since merely an indication as to the general trends of certain features was desired. The fact that all mills were not covered by the reporting concerns, while a matter to be regretted, was not one to void the success of the inquiry.

The establishments to which schedules were sent in this inquiry were those equipped for the manufacture of groundwood and chemical fiber in the United States as listed in "Post's Paper Mill Directory: 1915," which presumably covers the 1914 equipment. The individual schedules were summarized in various ways and those items of most interest to the public are given in condensed form as follows:

SUMMARY OF PULPWOOD DATA

NOTE.—Amounts are expressed in standard stacked cords of 128 cu. ft. each. The "wood waste" in question, otherwise called "sawmill waste," or "mill waste," consists of slabs, trimmings, edgings, shavings, cores and other similar wastes of sawmills, planing mills, and other wood working establishments. Items 4 and 5 are estimations based on the reasonable assumption that the plants not reported upon must have consumed on the average as much wood in proportion to their capacities as did the reporting concerns (see item 3); the great preponderance of the latter (90:10) minimizes any inaccuracy in this regard. So far as could be learned from outside sources there was no marked variation in the proportion of idle and operating plants among those not reporting as compared to the others.

1. Total number of pulp mills in U. S. A., 250; proportion of same covered by reporting concerns, 90.0 per cent.

2. Total potential wood-consuming capacity of all pulp mills, 6,499,760 cords per annum; proportion of

such potential capacity covered by reporting concerns, 82.1 per cent.

3. Ratio of actual pulpwood consumed to potential capacity, for reporting concerns, 66.0 per cent; ratio of wood waste used as pulpwood to total pulpwood, 7.7 per cent.

4. Estimate of total pulpwood (including wood waste) consumed by all mills whether reporting or not, about 4,290,000 cords; estimated cost, about $36,800,000.

5. Estimate of total wood waste used as pulpwood by all mills whether reporting or not, about 330,000 cords; estimated cost, about $1,400,000.

6. Distribution of wood waste used as pulpwood by reporting concerns, according to process of manufacture; mechanical, 3 per cent; sulphite, 76 per cent; sulphate, 13 per cent; soda, 8 per cent.

7. Average costs per cord delivered at mills of reporting concerns; for pulpwood of all kinds $8.58; for wood waste, only, $4.25.

8. Classified costs of pulpwood of all kinds and of specified kinds, delivered at mills is given in Table I.

TABLE I

Cost per Cord	Number of Reporting Concerns				
	Pulpwood*, All Kinds	Rough Wood	Peeled Wood	Rossed Wood	Wood Waste
$ 0-$0.99	1	0	0	0	3
1.00- 1.99	0	0	0	0	0
2.00- 2.99	3	1	1	0	3
3.00- 3.99	1	2	0	0	6
4.00- 4.99	7	4	1	0	3
5.00- 5.99	13	4	0	0	6
6.00- 6.99	14	12	5	0	1
7.00- 7.99	16	12	7	0	2
8.00- 8.99	22	16	9	1	1
9.00- 9.99	28	25	7	3	3
10.00-10.99	28	10	24	2	0
11.00-11.99	14	5	17	1	1
12.00-12.99	11	1	6	9	0
13.00-13.99	7	0	2	14	1
14.00-14.99	6	0	0	13	0
15.00-15.99	4	0	0	4	0

*For example, 7 concerns paid between $4 and $5 for the average cord of wood used by each n 1914, regardless of form whether rough, peeled, rossed or waste.

EXPLANATION OF ITEMS

Items 1, 6, 7 and 8 were obtained solely from the schedules.

The potential wood consuming capacity as given under item 2 is a hypothetical value signifying the greatest amounts of wood that all the pulp mills of the United States could use in a year if they were to operate at full rated capacity 360 days for mechanical mills and 310 for chemical mills. This value, which was needed for making the estimates in items 4 and 5, was obtained from the pulp producing capacities of the mills as recorded in Post's Paper Mill Directory, 1915, assuming one ton of mechanical pulp equivalent to one cord of wood, and one ton of chemical pulp equivalent to two cords of wood. Obtained in this way the value itself may or may not be anywhere near correct; for the purpose at hand, it really matters little how far off it may be. The important thing is that it will be as nearly correct for all of the mills as the similarly obtained value (3,522,108 cds.) is for the reporting concerns, and the resultant ratio (82.1 per cent) between the two values must be quite accurate in consequence.

The data under item 3, obtained jointly from the schedules and from item 2, show that the reporting pulp mills operated to practically two-thirds (66.0 per cent) of their "potential capacity" during 1914, while of the total pulpwood reported 7.7 per cent was wood waste. The estimates of amounts of pulpwood and of wood waste under items 4 and 5 assume that these same ratios hold good for all of the American pulp mills including the small number (10 per cent) or small capacity (17.9 per cent) not actually reported upon. Even if the ratios for the non-reporting mills alone were as much as 30 per cent off from the average of the reporting concerns, it would put the estimates in error by only about 5 per cent and, moreover, it would be scarcely believable that every last one of the twenty-five non-reporting mills were operated under such phenomenally good (or phenomenally poor) conditions that their individual variations from the average would all be in the same direction to the extent of 30 per cent or any other large proportion. The natural tendency would be for these individual variations to practically offset each other. Likewise, the estimated costs under items 4 and 5 are based on assumptions that the average prices per cord for the reporting concerns (item 7) would very nearly hold good for all of the mills, but they, of course, are purely rough approximations.

It should be noted that the percentage distribution of pulpwood by processes of manufacture, as given under item 6 apply only to the wood waste and not to the great bulk of total pulpwood.

The average costs under item 7 were obtained by dividing the total costs of all wood reported upon by the total number of cords reported with cost figures accompanying.

In item 8 the number of concerns noted under the several kinds of pulpwoods reported does not signify number of establishments or mills. This is of importance since some of the reporting concerns recorded a single cost figure to apply to two or more mills, under the same local management, for which no distinction was made in figuring wood costs.

In view of the above explanation as to just how the several figures were obtained there is no apparent objection to making them public. The "estimates" in particular are given for whatever they may be worth in the opinion of those finding use for them and the only assurance which can be given as to their ultimate reliability is that they are as accurate as the mill reports and the statistical laws of averages will afford under carefully checked compilations.

Assuming the figures above to be measurably correct, it is interesting to compare them with similar figures for previous years and thus get an idea as to where the wood pulp industry stands to-day. Table II will serve this purpose:

TABLE II—CONSUMPTION OF PULPWOOD BY UNITED STATES MILLS

Year	Pulpwood, All Kinds* Cords	Wood Waste Only Cords	Authority
1914	4,290,000	330,000	Unofficial estimates
1913	.....	.....	No data available
1912	.....	.....	No data available
1911	4,328,052	280,534	Forest Service and Bureau of Census
1910	4,094,306	262,637	Forest Service and Bureau of Census
1909	4,001,607	248,977	Forest Service and Bureau of Census
1908	3,346,953	(a)	Forest Service and Bureau of Census
1907	3,962,660	(a)	Forest Service and Bureau of Census
1906	3,661,176	(a)	Forest Service and Bureau of Census
1905	3,192,223	(a)	Forest Service (H. M. Hale)
1899	1,986,310	(a)	Bureau of Census

(a) Not reported separately.
*These figures cover both domestic and imported goods.

It is a matter of surprise that the figures of Table II show the American wood pulp industry to have declined since 1911, although it is well recognized in the trade that the United States production of pulp from wood has not been keeping up with the actual domestic consumption of pulp and paper products. Even were the 1914 figures too low by 5 per cent, the industry apparently would not have made the normal gain during the last three years that its previous record warranted.

In seeking reasons why the American industry made little or no progress in 1914, one finds two important factors, aside from the previous large and steadily increasing importations of European pulps, that would have operated either separately or in combination to bring this about. In the first place, 1914 was a year of severe depression for business in general; the next preceding year of severe business depression was in 1908, which is similarly reflected in a decreased wood consumption for that year, as compared with both 1906 and 1907. On the other hand, consideration cannot be given the possibly waning industry of this country without reference to the vigorous growth of the Canadian industry during the last few years, inasmuch as the greater portion of its products (*e.g.*, something like nine-tenths of its news print) is marketed in the United States. While general business depression in 1914 was as pronounced in Canada as in the United States, yet the Canadian wood pulp industry continued its remarkable development. A comparison of the United States record, as above, with that of Canada, as given in the following excerpt from the *Papermill and Wood Pulp News*, Aug. 7, 1915, page 18, is quite enlightening:

"Canadian statistics show that the consumption of pulpwood in Canada increased nearly 10½ per cent in 1914, compared with 1913. Since 1910 the increase has been 104 per cent. The 66 active pulp mills in Canada in 1914 consumed 1,224,376 cords of pulpwood, valued at $8,089,868, while in addition to this 972,508 cords valued at $6,680,490, were exported in an unmanufactured state. In 1914, 55.7 per cent of all pulpwood produced in Canada was made into pulp in Canada and 44.3 per cent was exported, chiefly to the United States in the raw or cordwood state. Formerly, only one-third of the pulpwood produced in Canada was made into domestic pulp."

Disregarding all artificial restrictions on the course of trade, it is but the natural outcome that the wood pulp industry should gravitate more and more from the eastern United States to Canada, from a region where pulp wood is becoming scarce and costly to one of more abundant and cheaper timber. In time, the present manufacturing regions, even in Canada, will have to yield likewise to other and newer sources of supply.

While other natural resources and facilities than timber are of importance, it is not necessary to look further than the 1914 figures on American pulp wood costs (item 8 above) to understand how Canada, with an average wood cost of about $6.50 per cord and with legislation as well as sentiment restricting the exports of pulp wood, has been able to attract the industry, even though the market is on the American side.

Something like one-third of the United States companies are now paying from $10 to $16 per cord for their entire supply of wood and, without prospect of relief in sight, realize the outcome of trying to compete with mills more favorably circumstanced. In consequence, a number of American operators have been acquiring Canadian interests, but some, unwilling to forsake purely domestic manufacture, are of the opinion that it might be better to transfer their energies and resources from the wood pulp industry to other lines of endeavor.

Still others, neither willing to move to Canada nor wishing to abandon the industry altogether, may sooner or later find it worth while to shut down their Eastern plants and operate in southeastern Alaska or in the West, where water power is absurdly cheap and eminently suitably pulp timber from the National Forests, at least, can be delivered to desirable mill sites for the next twenty to forty years at prices of about $2.50 to $4 per cord, covering all charges, and this without any investment in timberlands, without taxes or fire risks.

It is at least significant that the enormous savings they could affect in wood costs per ton under such conditions would more than offset the higher freight rates they would have to pay to bring finished paper or chemical pulp to their original Atlantic seaboard markets without trying to enter new ones. Even the 1915 marine rate of 40 cents from coast to coast is not particularly discouraging under such considerations.

In consequence of existing conditions and of those to be expected, there are already specific opportunities for Western enterprises that will doubtless excite the curiosity of some of the Eastern operators if not their more serious consideration. Of course, real difficulties in the way of such new developments must be expected, but the risks are growing less each year and close investigation eliminates many of the usual stock objections.

The signs of the times indicate that if the United States is to retain its pre-eminence in wood pulp manufactures it will evidently have to make use of its wonderful Western and Alaskan resources. Even the use of wood waste, as indicated by the above tabulation, while encouraging in the steady progress that has been made, does not at present seem sufficient to warrant the hope that it will be the predominant factor in keeping our industry at home.

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Extraction of Gold and Silver from Matte by Lead*

BY W. MOSTOWITSCH

In practice there are two different processes for the extraction of the noble metals from materials containing gold and silver.

1. Smelting with lead ores or lead-carrying materials in the blast furnace. The resulting base bullion is desilverized and the gold and silver parted.

2. Treatment of mattes and speises with molten lead (Crooke and Davies). The treatment of copper matte with molten lead for the removal of gold and silver is still used in Japan (Bull. A. I. M. E., Nov., 1914, p. 2693).

The results from practice show in general that the gold collects chiefly in the base bullion, the silver dividing itself between base bullion and matte. The percentage extraction of silver is lower, the greater the amount of matte for the same amount of base bullion. This fact is illustrated by table III in an article by M. Ortin (Metall und Erz, 1913, p. 840).

Experimental results are given in an article by S. Blisinski (Chemik Polski, XII, 1912, No. 8). He made a series of synthetic mattes by melting together FeS (Fe = 70.25, S = 25.54 per cent) with Cu_2S (Cu = 78.8, S = 20.98 per cent) in such proportions, that the resulting mattes contained about 25 per cent copper. These mattes were repeatedly remelted with powdered silver and gold. Thirty grams of this material was then melted with lead in a muffle furnace in a graphite crucible. In these tests the quantity of the lead, the temperature, and the duration of the melting were varied. In the resulting product lead, gold, and silver were determined. The first series of experiments were made with mattes A and B of the following analyses:

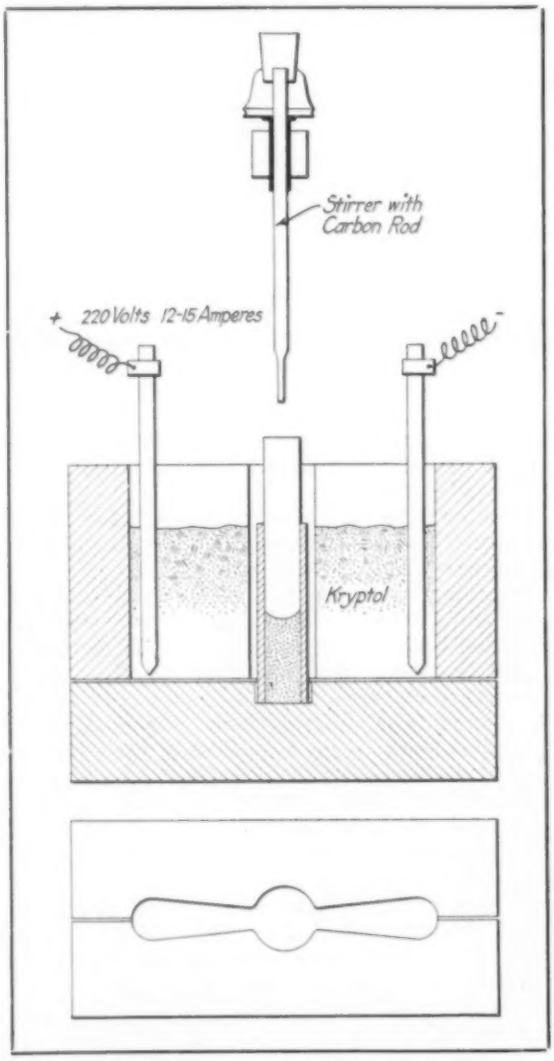
	Ag	Cu	Fe	S
A	7.32	17.10	46.80	25.24
B	8.80	17.50	44.95	25.18

Thirty grams each of A and B were melted with 15 to 120 gr. Pb at 1000, 1100 and 1250 deg. C. for from 45 to 90 minutes.

*Translated in abstract from the Journal of the Russian Metallurgical Society, 1914, No. 4, pp. 511 to 532.

The results of these experiments showed that lead extracted 72 to 93.8 per cent of the silver; the percentage extraction increased as the amount of lead increased and it also increased with rising temperature but decreased as the time of heating increased.

Experiments were made with a gold-containing matte of the following composition: Au 1,247, Cu 17.65, Fe 49.90, S 27.77. Thirty grams of matte were melted with 30 to 90 gr. of lead at 1000, 1100, and 1250 deg. for 45, 90 and 135 minutes. According to the analyses the extraction of gold was influenced much less by the amount of lead than was the extraction of silver. When the lead varied in amount from one to three times the weight of the matte, the gold extraction varied between 95.2 and 99.3 per cent. The temperature and time of heating had very little effect.



EXPERIMENTAL ELECTRIC FURNACE

From these experiments it appears that a contact between the lead and gold is sufficient to obtain an extraction of 93.3 to 99.3 per cent, still under the same conditions the solubility of the gold in lead is higher than the silver. If we assume the ratio of the weights of Pb to matte to be n, and the per cent extraction of the silver = P_{ag}, that of the gold = P_{au}, we have:

		n = 1	n = 2	n = 3
At 1000 deg. C. and 45 min. heating	P_{ag}	83.47	91.35	90.62
	P_{au}	99.06	98.77	98.87
At 1100 deg. C. and 45 min. heating	P_{ag}	82.92	93.85	93.58
	P_{au}	96.87	99.33	99.14

The solubility of the gold in lead is so great that the change from $n = 1$ to $n = 3$, has not much effect on the extraction. It is interesting to note what the minimum amount of lead is, which will extract all the gold. For copper we have the researches of Gibb (H. O. Hofman, Metallurgy of Copper, p. 295).

Experiments were made in our laboratory as follows: Twenty grains of a gold-carrying matte were melted in a cryptol furnace in Tammann carbon tubes at 1050 deg. C. with different amounts of lead. Stirring was done with a carbon rod. The copper matte contained Cu 36.92 per cent, Fe 36.98, S 24.40, Au 0.00335 per cent, Ag 0.0354 per cent. The results are given in Table I.

The following conclusions may be drawn:

1. The percentage extraction of the gold and silver is proportional to the amount of lead added.

2. With an amount of lead equal to 80 per cent of the weight of the matte practically all the gold is extracted.

3. The extraction of the silver reaches only 72 per cent with equal amounts of lead and matte.

The form in which gold and silver exist in mattes is not yet fully established. It may be assumed that the silver is combined as Ag_2S, while it is possible and quite probable that the gold occurs uncombined, or alloyed with the sulphides or metals in the matte. Evidence in favor of the assumption as to silver, is found in the difficulty of the extraction of the silver. The decomposition of Ag_2S by lead according to the equation

$$2\ Ag_2S + 2\ Pb \rightarrow Ag_2Pb + Ag_2S.\ PbS$$

proceeds to the formation of an alloy $Ag_2S.\ PbS$, and as a result the extraction of the silver through a single treatment with lead cannot be accomplished.

Experiments were made to clear up this question. The experiments were also intended to show whether lead treatment of the matte could be used as a method for the analytical determination of the gold in the matte since the known analytical methods for this purpose are too

TABLE I

Experiment No.	Matte, Gr.	Lead, Gr.	Au in Matte, Mgr.	Ag in Matte, Mgr.	Matte + Lead After Melting, Gr.	Base Bullion, Gr.	Au and Ag in Base Bullion		Extraction in per Cent		Remaining in Matte After Extraction			
							Au, Mgr.	Ag, Mgr.	Au	Ag	Au, Mgr.	Ag, Mgr.	Au, per Cent	Ag, per Cent
1	20	4	0.67	7.08	23.5	1.8	0.35	1.95	52.24	27.54	0.32	4.97	48.8	70.26
2	20	6	0.67	7.08	25.3	3.4	0.44	2.46	65.67	34.75	.....	.....	.....	.....
3	20	8	0.67	7.08	27.3	4.6	0.50	3.00	74.63	42.37	.....	.....	.....	.....
4	20	8	0.67	7.08	27.6	4.9	0.50	3.10	74.63	43.78	.....	.....	.....	.....
5	20	10	0.67	7.08	29.7	7.1	0.57	3.58	85.1	50.57	.....	.....	.....	.....
6	20	10	0.67	7.08	29.3	7.0	0.57	3.63	85.1	51.27	.....	.....	.....	.....
7	20	12	0.67	7.08	31.3	9.6	0.65	3.95	97.01	55.78	.....	.....	.....	.....
8	20	12	0.67	7.08	31.2	9.3	0.65	3.95	97.01	55.79	0.015	3.28	2.24	46.38
9	20	14	0.67	7.08	33.4	10.5	0.66	4.04	98.50	58.62	.....	.....	.....	.....
10	20	14	0.67	7.08	33.2	10.8	0.66	4.04	98.50	58.62	0.01	2.90	1.50	42.23
11	20	16	0.67	7.08	35.2	12.4	0.67	4.18	100	59.04	.....	.....	.....	.....
12	20	18	0.67	7.08	37.2	15.3	0.67	4.53	100	63.98	.....	.....	.....	.....
13	20	20	0.67	7.08	38.6	16.8	0.67	5.08	100	71.75	.....	2.0	.....	28.25

long, too complicated and too costly. Six mattes of the composition shown in Table II were tested.

TABLE II

	In per Cent					Mgr. in 10 Gr.	
	Cu	Pb	Fe	Zn	S	Ag	Au
Matte I.	28.12	0.72	40.15	1.51	24.79	2.06	0.29
Matte II.	11.90	0.86	49.85	....	24.95	17.52	4.73
Matte III.	19.71	4.19	42.58	....	25.85	22.13	1.83
Matte IV.	41.23	7.15	24.52	....	22.72	49.44	9.52
Matte V.	66.88	8.68	2.61	....	18.40	5.262	0.44
Matte VI.	46.42	19.65	0.23	1.25	17.60	1300	22.8

Mattes I to V are crude and concentrated mattes from copper and copper-lead smelting at Ural smelters.
Matte VI was obtained from gold-zinc precipitates from a gold mine.

Experiments were made with 10 to 15 grams of matte heated in carbon tubes in a cryptol furnace at 950-1000 deg. C., whereupon 10 to 25 grams of lead were added. To accelerate the extraction, the melt was stirred with a carbon rod. At all temperatures the melt forms two layers, namely lead and matte. The contents were then placed in a crucible which was heated to full redness in an electric furnace. At one and the same temperature the extraction of the noble metals depended on the amount of lead and duration and intensity of stirring. The effects of these factors were tested with the results given in Table III.

The experiments were made with mattes of different origin, character, and gold and silver content. Nevertheless, the extraction of the gold was about 100 per cent, that of the silver 64.4 to 96 per cent. From forty-four tests it is seen that the extraction of the gold is independent of the ratio of the weights of lead and matte, and also independent of the duration and intensity of agitation.

For mattes I and II, the ratio of the weights of lead to matte varied between 1 and 2.5.
For mattes III-V, the ratio of the weights of lead to matte varied between 1.5 and 2.5.
For matte VI, the ratio of the weights of the lead to matte varied between 2 and 6.

The duration of agitation varied between 5 and 15 minutes, the intensity of agitation between 300 to 650 rotations per minute and under all these conditions the extraction of the gold was 100 per cent. For silver, the extraction increased with the ratio of lead to matte.

For matte II—	n = 1.	Extraction = 81.2
	n = 1.5	84.0
	n = 2.0	92.2
	n = 2.5	96.0
For matte III—	n = 1.5	79.0
	n = 2.5	90.9
For matte IV—	n = 1.5	83.0
	n = 2.5	87.0
For matte VI—	n = 2	75.9
	n = 4	86.1
	n = 6	90.8

The variation of the time and intensity of agitation had but little effect on the extraction as shown by the following:

Matte IV.	10 min. 500 rotations per min. extraction	42.97
	5 min. 200-300 rotations per min. extraction	40.95

The relation between the percentage extraction of the silver and the copper content of the mattes is evident from Table IV.

TABLE III

Experiment No.	Agitation					Base Bullion, Gr.	Cu in Matte, per Cent	In 10 Gr. of Matte		In Base Bullion		In 10 Gr. Matte After Agitation		Extraction			
	Matte No.	Matte, Gr.	Lead Added, Gr.	Time of Heating, Min.	Rotations of Stirrer per Min			Ag, Mgr.	Au, Mgr.	Ag, Mgr.	Au, Mgr.	Ag, Mgr.	Au, Mgr.	Mean Ag, Mgr.	Mean Au, Mgr.	Ag, per Cent	Au, per Cent
1	II	10	10	10	650	8.8	11.9	17.52	4.73	14.35	4.75	.....	.....	.....	.....	.....	.....
2	II	10	10	10	650	8.1	11.9	17.52	4.73	14.50	4.75	3.6	.....	14.23	4.78	81.2	100
3	II	10	10	10	650	8.9	11.9	17.52	4.73	13.85	4.85	.....	.....	.....	.....	.....	.....
4	II	10	20	10	600	18.8	11.9	17.52	4.73	16.25	4.75	.....	.....	.....	.....	.....	.....
5	II	10	20	10	600	19.0	11.9	17.52	4.73	16.05	4.75	2.1	.....	16.15	4.75	92.2	100
6	II	10	25	10	600	23.7	11.9	17.52	4.73	17.12	4.78	.....	.....	.....	.....	.....	.....
7	II	10	25	15	600	23.9	11.9	17.52	4.73	16.52	4.78	1.5	.....	16.82	4.78	96	100
8	II	10	15	5	310	14.0	11.9	17.52	4.73	14.60	4.70	.....	.....	.....	.....	.....	.....
9	II	10	15	5	310	13.5	11.9	17.52	4.73	14.85	4.80	.....	.....	14.72	4.75	84	100
10	III	10	25	10	340	23.8	19.71	22.13	1.83	19.95	1.85	.....	.....	.....	.....	.....	.....
11	III	10	25	10	340	24.4	19.71	22.13	1.83	20.55	1.85	.....	.....	20.10	1.83	90.9	100
12	III	10	25	10	340	23.9	19.71	22.13	1.83	19.70	1.80	.....	.....	.....	.....	.....	.....
13	III	10	25	10	340	24.3	19.71	22.13	1.83	20.20	1.80	.....	.....	.....	.....	.....	.....
14	III	10	15	5	310	14.0	19.71	22.13	1.83	17.15	1.85	.....	.....	.....	.....	.....	.....
15	III	10	15	5	310	14.0	19.71	22.13	1.83	17.30	1.85	.....	.....	17.47	1.85	79	100
16	III	10	15	5	310	14.0	19.71	22.13	1.83	17.95	1.85	.....	.....	.....	.....	.....	.....
17	IV	10	25	15	500	24.7	41.23	49.44	9.52	43.9	9.40	.....	.....	.....	.....	.....	.....
18	IV	10	25	15	500	24.8	41.23	49.44	9.52	42.2	9.30	.....	.....	42.97	9.33	87	98
19	IV	10	25	15	500	24.7	41.23	49.44	9.52	42.8	9.30	.....	.....	.....	.....	.....	.....
20	IV	10	15	5	200	14.7	41.23	49.44	9.52	41.25	9.70	.....	.....	.....	.....	.....	.....
21	IV	10	15	5	300	14.2	41.23	49.44	9.52	40.85	9.55	.....	.....	40.95	9.62	83	100
22	IV	10	15	5	300	14.5	41.23	49.44	9.52	40.75	9.60	.....	.....	.....	.....	.....	.....
23	V	10	25	15	370	25.6	66.88	52.65	0.44	41.58	0.52	.....	.....	.....	.....	.....	.....
24	V	10	25	10	310	25.5	66.88	52.65	0.44	41.60	0.50	.....	.....	41.15	0.50	78.1	100
25	V	10	25	10	310	26.0	66.88	52.65	0.44	40.7	0.50	.....	.....	.....	.....	.....	.....
26	V	10	25	10	310	25.2	66.88	52.65	0.44	40.7	0.50	.....	.....	.....	.....	.....	.....
27	V	10	15	5	300	15.5	66.88	52.65	0.44	33.80	0.43	.....	.....	33.93	0.43	64.4	100
28	V	10	15	5	300	15.7	66.88	52.65	0.44	33.82	0.43	.....	.....	.....	.....	.....	.....
29	V	10	15	5	300	15.1	66.88	52.65	0.44	34.17	0.43	.....	.....	.....	.....	.....	.....
30	I	10	25	10	340	23.8	28.12	2.06	0.29	2.6	0.26	.....	.....	.....	.....	.....	.....
31	I	10	25	10	340	23.6	28.12	2.06	0.29	2.3	0.26	.....	.....	2.4	0.28	100	100
32	I	10	25	10	340	24.0	28.12	2.06	0.29	2.4	0.30	.....	.....	.....	.....	.....	.....
33	I	15	15	5	300	13.0	28.12	3.09	0.45	3.45	0.50	.....	.....	.....	.....	.....	.....
34	I	15	15	5	300	13.0	28.12	3.09	0.45	3.45	0.47	.....	.....	3.34	0.49	100	100
35	I	15	15	5	300	13.0	28.12	3.09	0.45	3.13	0.50	.....	.....	.....	.....	.....	.....
36	VI	5	10	5	300	....	46.42	650	11.4	502.05	11.55	.....	.....	.....	.....	.....	.....
37	VI	5	10	5	300	....	46.42	668	11.62	510.85	11.55	163.5	.....	506.92	11.55	79.90	99.4
38	VI	5	10	5	300	....	46.42	668	11.62	507.85	11.55	.....	.....	.....	.....	.....	.....
39	VI	5	20	5	300	....	46.42	668	11.62	575.8	11.60	.....	.....	.....	.....	.....	.....
40	VI	5	20	5	300	....	46.42	668	11.62	581.5	11.90	92.5	.....	575.4	11.66	86.1	100
41	VI	5	20	5	300	....	46.42	668	11.62	568.9	11.50	.....	.....	.....	.....	.....	.....
42	VI	5	30	5	300	....	46.42	668	11.62	612.5	11.50	.....	.....	.....	.....	.....	.....
43	VI	5	30	5	300	....	46.42	668	11.62	609.51	11.60	67.0	.....	606.4	11.53	90.8	99.4
44	VI	5	30	5	300	....	46.42	668	11.62	597.1	11.50	.....	.....	.....	.....	.....	.....

Table IV

n = Lead to Matte	Per Cent Cu in Matte				
	11.90	19.71	41.23	46.42	66.88
	Extraction per Cent				
1.5	84	79	83	.....	64.4
2	92.2	.....	.....	75.9	.....
2.5	96	90.9	87	.....	78.1

For the same weight ratio of lead to matte the extraction of the silver decreases with increasing copper content.

Such an easy and complete extraction of the gold from the mattes makes it probable that the gold exists in matte in the free state, as a mechanical mixture. This view is also supported by the fact that gold occurs in a similar free form in most natural sulphides whereby the extraction by cyanide solution is explained. The silver occurs in matte chiefly as Ag_2S. Accordingly the extraction of the silver depends on the breaking up of this compound as follows:

$$2\ Ag_2S + 3\ Pb = 2\ Ag.\ Pb + Ag_2S.\ PbS$$

This reaction proceeds, as is known, to the formation of a new matte system. In our case $Ag_2S.\ PbS$ is formed and when the concentration of the silver in both phases —matte and base bullion—reaches a certain amount, the action of the lead on the newly formed matte ceases and an equilibrium is established between both products.

The lowering of the silver extraction with increasing copper content in copper mattes shows that the copper component of the matte (Cu_2S) binds the silver and on that account the value of the final concentration of the silver in the matte is raised. The lead then loses its action on the Ag_2S. According to the phase diagrams of Friedrich (Metallurgie, IV, 1907, p. 171) it can be seen that out of several sulphides which occur in matte, Cu_2S and Ag_2S form mixed crystals. This indicates that the two sulphides have a large mutual solubility, and this explains the decreasing silver extraction from copper matte, as the copper content increases.

The complete extraction of gold from matte by agitation of the melt with lead, together with the simplicity and ease of operation of the process, indicates the possibility and desirability of the application of this process to quantitative determinations of gold in mattes. This method requires only 2 or 2½ hours, divided as follows: Agitation, 10 minutes; slagging of the base bullion once or twice, 1½ hours; cupellation, etc., 1 hour. A very small amount of reagents is required and the manipulation is simple.

Tomsk, Russia.

Many Industries Represented in Exhibit of Waterworks Appliances.—An exhibition of waterworks appliances was held in the ballroom of the Hotel Astor, New York, in conjunction with the annual Waterworks Convention held June 5 to 9. Among the companies represented were the following: Eimer and Amend, New York (chemicals, laboratory supplies, water stills, etc.); U. S. Cast Iron Pipe & Foundry Co., Burlington, N. J. (cast iron pipe); Bristol Company, Waterbury, Conn. (recording pressure, temperature, and other gages); Worthington Pump & Machinery Co., New York (pumps and all kinds of machinery); Mogul Company, New York (acid-resisting coating for pipes, tanks, etc.); American Bitumastic Enamels Co., New York (non-corrosive enamels); Lead Lined Iron Pipe Co., Wakefield, Mass. (lead-lined iron pipe); Electro Bleaching Gas Co., New York (chlorine).

Flotation Versus Cyanidation

BY JACKSON A. PEARCE

As a factor in ore dressing, flotation is occupying a prominent place and may as well be considered a fixture. Results on lead, copper, and zinc ores are especially gratifying the world over. With these ores the process is additional rather than substitutional. In some instances, jigs, vanners and buddles have been eliminated from the flow-sheet, but as a distinct substitutional process it has found but limited application. In some mills it is true it has substituted cyanidation in the treatment of certain gold and silver-bearing pyritic ores, yet it has not met with the same general success as in its application to lead, copper and zinc ores.

At the Argo mill[1], Idaho Springs, Colo., some interesting parallel tests have been carried out to show the relative merits of flotation and cyanidation on these pyritic ores. Since November, 1913, I have been treating at this mill a large variety of sulphide ores by concentration and cyanidation. The extraction of the gold has been satisfactory—from 88 per cent to 98 per cent. The extraction of the silver has been less satisfactory—from 50 per cent to 65 per cent. As the mill is supplied exclusively by custom ore, there is an evident limit to the amount of silver an ore may carry and leave a profit to the mill, and with our schedule that limit is not very high.

At the time the tidal wave of flotation flooded this part of the United States we were engulfed to the extent of making numerous and extensive laboratory tests. These tests were satisfactory. However, the success attending the cyanidation of these ores coupled with a later discontinuance of some of the flotation machines installed nearby, mollified our enthusiasm and held flotation in abeyance. It was only when much of the custom ore showed a continued increase in silver that serious attention was paid to flotation.

Difficulties of Operation

To accommodate these ores a flotation unit was installed, giving us two distinct flow-sheets in the mill. The installation of the flotation machine was a simple matter, much simpler than the successful operation of it. Preliminary tests on the silver ore gave an extraction ranging from 87 per cent to 90 per cent, and as much, or nearly as much, was expected in operation. For the first two weeks the new system was a very discouraging affair. It is impossible to state just what the extraction was during this period, for the assays of the discharge averaged slightly higher than those of the feed, erratic sampling accounting for the discrepancy. One thing certain is that on an ore concentrating 4 into 1, not over 1000 lb. of concentrates was produced by flotation during this period. This concentrate was largely lead and zinc, with some copper and pyrite, and an abundance of silica.

Then followed a distressing period of more than two months of alteration and variation. Ore was coming in at a rate sufficient to keep the entire mill in operation. The extraction on the tables was 50 per cent, on the flotation machine nil. To adjust the system to yield a reasonable extraction and at the same time to keep from under the ore, imposed a feverish condition upon us. To begin with, those changes were made that seemed logical to us. Those failing, we resorted to guess work.

"An oil for every ore" was a slogan that consumed a large amount of valuable time. Having tried all the

[1]See description of cyanide practice, Met. & Chem. Eng., July, 1915, vol. XIII, p. 421.

oils from which good results were obtained in the preliminary tests with negative results, we essayed those oils and combinations reported to have given good extraction on these and similar ores. Improvement was not noticeable. Acting on the advice of a reputable flotation metallurgist we studied the effect of the sequence of oils. The sequence of oils, in his personal experience, had made the difference between success and failure. We followed one oil with another throughout the entire plant, then reversed the order. We added oil at every stage of the process from the battery bin to the tail race. The desired results were not forthcoming. Of the oils used, mention may be made of Nos. 75, 350, 400 and 750 of the Pensacola Tar & Turpentine Company, a few pine oils of local brand, refined turpentine, coal tar creosote, coal tar, coal oil, gasoline, asphalt, engine oil, fuel oil and some crude oils.

In desperation we assaulted the machine to satisfy the most trivial suggestions, such as to taking out the baffles, to increasing the submergence, to decreasing the flow, to putting the baffles back, to adding air from an external source. We varied the speed of the agitators from almost nothing up to the overload rate of the motor, giving us a peripheral speed greatly in excess of that generally deemed sufficient. We decreased the size of the agitation cells, and increased the length of the impellers. In short, the only changes we did not make were those that did not occur to us.

Various Theories Considered

Then we attacked the problem from the standpoint of modern theories of flotation, whether generally accepted or not. Durell's theory of occluded gas, and those two closely related theories, the one of interfacial tension, the other of electrostatics, advocates of each of which are to be found among the ablest men in the field of flotation. We put all tangible parts of these theories to the test, going to the absurd extreme of trying to induce electrification from without.

We made an examination of the electrolyte, thinking it at fault, perhaps containing some vitiating soluble constituent of the ore. Or perhaps it lacked certain solutes necessary to the proper electrostatic distribution. Although copper and ferrous iron were found in solution, they seemed in negligible quantities. Mr. Robert J. Anderson[2] points out that the salts of these two metals are harmful to the successful flotation of certain ores. Nevertheless, out of curiosity and because the system seemed to be following no established precedent, we increased the amounts of both salts—an increase could do no harm. We tried ferric salts and table salt, oxidizing agents and reducing agents. Yes, we tried acids, both organic and inorganic. Somehow we succeeded in "diminishing the contractile force in the elastic membrane constituting the film of the bubble," yes, indeed. We had oceans of froth but no pyrite. With an acid electrolyte this voluminous froth carried a superabundance of silica.

Following Durell's line of reasoning, all that is necessary to rid the froth of silica is to increase the osmotic pressure just sufficiently to expel the occluded gas of the silica, yet not sufficiently to expel all the occluded gas of the metallic sulphides. This is done by increasing the ions of the electrolyte, i.e., by the addition of some easily dissociated solute, say sulphuric acid. Accordingly, we added more sulphuric acid, starting with ½ lb. per ton and increasing gradually to 20 lb. per ton. This did not succeed.

Now if we view the conditions in the light of the electrostatic theory we might suspect in so far as the attraction is concerned that the silica and the films were oppositely charged. In an acid solution this should not be the case, since both oil and air are supposed to be negatively charged at all times, and colloidal silica negatively charged in an acid solution. However, as colloidal silica reverses its polarity with respect to hydrogen and hydroxyl ions, and as no harm would result in reversing the polarity of the silica, we changed from acid to alkaline solution. This made a marked difference in the character of the froth, but an improvement in extraction was not noticeable.

Vagaries of the Process

These theories undoubtedly are of great assistance to the well posted and experienced, but to the uninitiated such as we are they were conducive to no better work than would have been a germ theory of flotation.

We then turned our attention to consistency, trying every step from clear water to mud. And temperature was given a wide range. Told that the machine was overloaded, we reduced the feed gradually to 1/40 its rated capacity.

Such unscientific hit-or-miss tactics ordinarily would visit the contempt of the metallurgical fraternity upon an operation. But such is the obscure and undeveloped state of the theory of flotation, and such the secrecy obtaining until recently as to working details, that only the few are able to examine an ore and prescribe a method of treatment with assurance. The history of flotation is a series of records of variations of conditions and alterations of plants extending over months, and even years.

Distinguished flotation metallurgists whom we consulted were not able to point with conviction to the critical defects in the system. All the many suggestions, and they were thankfully received, were carried out to the letter, yet were they barren of results.

Eventually flotation succeeds, and success is ascribed to certain details of operation. Yet these same details, so essential in one plant, seem of no consequence in another. Compare, as for instance, this plant with the one the success of which depended upon the sequence of oils. These two plants were built by the same engineer, from the same blueprint, of the same size, operating at the same speed, on the same ore, with the same oils, same consistency, same temperature, and as nearly same conditions throughout as possibly could be obtained. In one plant careful and repeated tests seemed to show beyond any question that the sequence of oils was of vital importance, yet in this plant it hadn't the slightest influence. Flotation is successful, but the reasons therefor are not manifest. Flotation in practice is yet far in advance of flotation in theory. With all due respect to the brilliant work now being done along this line, the question still is, "Why is flotation?"

Steady Improvement in Results

In the meantime the extraction was slowly improving. The lead and zinc minerals seemed to respond nicely from the beginning. The gold-bearing pyrite and the silver minerals were obstinate to the last. The extraction by periods showed 50 per cent (due to tables only), 63.3 per cent, 82 per cent and 92 per cent. However difficult it was to attain this last extraction, it was not difficult to maintain.

During this trying period of several months the mill crew, especially the master mechanic, showed the keenest of interest, and to their patience and perseverance is largely due the ultimate success of the undertaking.

Having maintained an extraction of better than 90 per cent by flotation of an ore yielding only 70 per cent by cyanidation, another problem presented itself. As stated before, we were cyaniding successfully some ores

[2]This journal, Feb. 1, 1916.

high in gold but low in silver, and flotation was added merely to take care of the high-silver ores. Now, to maintain two systems in one mill may be cheaper than to maintain the two systems in two mills, but it is far from being less expensive than one system in one mill. From an economic standpoint we could sacrifice some extraction in one system by combining the two, or rather by eliminating one. This sacrifice in extraction depends on the difference in cost of operation and on the grade of the ore. The increased cost of maintaining both cyanidation and flotation, together with the encouraging results by flotation, led to a trial by flotation of those ores heretofore treated by cyanidation. The flotation of gold ore, free-milling to a large extent, has not been conspicuous for its success, and considerable doubt was entertained as to the outcome of the test. It is true that preliminary tests gave surprisingly good results. But many obstacles still lie in the path of the flotation metallurgist, and we had not the same confidence in laboratory tests by flotation as we had, for example, in cyanide tests. However, we had a good working margin.

Competitive Test by Cyanidation and Flotation

For this test, to continue seven days if the flotation results were at all encouraging, 60 tons of ore daily was divided between cyanidation and flotation, the rest of the mill being hung up. As to flotation, the first day's run exceeded our expectations. The second day's run exceeded cyanidation. The following five days' run, extraction alone considered, was one of the prettiest contests it has been my pleasure to witness. The variation in daily extraction did not exceed 2 per cent, with a seven days' average of 96.2 per cent for cyanidation against 96.5 per cent for flotation. This ore runs about 0.80 oz. gold, 1.50 oz. silver, is largely free-milling, and of all the ores in the district is best suited to cyanidation. It carries about 0.20 per cent copper, which is a slight detriment to cyanidation but a valuable asset to flotation.

Cyanidation was temporarily discontinued pending further mill tests by flotation. It is generally accepted and widely advertised that every ore requires an individual oil, "a particular oil for a particular ore," and it was considered advisable to make a more thorough investigation as to the oil requisites of the different ores before abandoning cyanidation altogether.

Cyanidation Abandoned

For a month or so mill tests were made on many of the ores produced within a radius of 15 miles. The extraction during this period averaged 95.01 per cent, as a consequence of which we have abandoned cyanidation. Some idea of the ores treated may be had from the table made from some representative ores.

Lot	Character of Ore	Gangue	Oz. Au.	Oz. Ag.	Approximate Ratio of Concentration	Remarks
1	Pyritic	Feldspathic	0.70	1.50	6:1	About 0.2 per cent copper
2	Pyritic	Quartzose	2.06	0.40	2:1	No lead, copper or zinc
3	Pyritic	Quartzose	1.16	2.00	25:1	Free milling
4	Chalcopyritic	Feldspathic	0.44	8.90	4:1	2.0 per cent copper
5	Pyritic	Talcose	0.62	4.40	15:1	No lead, copper or zinc
6	Pyritic	Feldspathic	0.18	11.60	3½:1	About 0.2 per cent each of lead, copper, zinc

During the test on these ores only one frothing oil was used, No. 400 of the Pensacola Tar & Turpentine Company, with a Wyoming fuel oil as carrier. Since then, out of curiosity, we have tried the oils that had failed in the earlier tests. These oils included crude wood oils, pine tar oils, crude wood creosote and crude turpentine, furnished by the Pensacola Tar & Turpentine Company and by the United Naval Stores. The extraction was good in all trials, the poorest of which would have been considered highly satisfactory had it been obtained earlier in the work. I have lost much of the esteem I once held for "an oil for every ore," am reconciled to "an oil for any ore," and do not hold in contempt "any oil for any ore." We also reverted to other conditions, such as to consistency, temperature, etc. Some of the best work done was during a cold snap, when we had to break the ice to remove the froth. The consistency seemed to have no further effect than as to the quantity of oil consumed per ton of ore.

As to why we were not successful in the beginning we are not able to say. Now that the oil, consistency, temperature and a few other conditions are out of the way we shall be able to locate at an early date, perhaps, the cause of so much disturbance.

Conditions obtaining at the present time are:

Ore—Pyritic, containing gold and silver and a small amount each of copper, lead and zinc.

Screen size—1 per cent + 60, 34 per cent + 200, 65 per cent — 200.

Consistency—5 or 6 to 1.

Temperature—Mill.

Oil—Wood creosote, 15 per cent; Wyoming fuel, 85 per cent; mixed and fed to the first cell at the rate of 3 lb. per ton of ore.

Acid—None.

Other reagents—None.

Peripheral speed—1200.

Argo Mill,
Idaho Springs, Col.

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Rapid-drying Paint.—In the *Bulletin de la Société D'Encouragement*, March-April, 1916, a report is given on a rapid-drying paint (Lory paint) made by the firm of Lorilleux Cie. The report was presented by Mr. ACH. LEVACHE, representing the Comité des Arts chimiques. As many as three coats can be given in one day. The rapid-drying is obtained by using, instead of refined linseed oil, linoxine or linseed oil solidified by oxidation, such as obtained in linoleum manufacture. This is dissolved in a small quantity of slightly acid amyl alcohol and then a considerable quantity of turpentine is added. When this solvent evaporates, the paint is completely dry, since the oil has been oxidized in advance.

The paint is sold in cans, already prepared, containing the pigment, such as zinc oxide, the oil and the turpentine. In one test made with the paint, a first coat was put on using three quarts at 9 o'clock, followed by a second coat of three quarts at 12 o'clock. The first coat did not roll under the brush when applying the second coat. A third coat of one quart was given at 2 o'clock. Other tests confirmed the above results. What the lasting qualities are, only time can tell, but in one case walls coated with the paint show no sign of deterioration after five years. The price of the paint in normal times would be a little higher than ordinary zinc paint, but its advantages in quick drying outweigh the extra cost in many cases where quick drying is desirable.

Solubility of Naphthalene in Ammonia.—In *Zeits. für Ang. Chemie*, Feb. 22, 1916, SIEGFRIED HILPERT discusses the solubility of naphthalene in water and liquid ammonia. Lunge in his "Steinkohlenteer" states that naphthalene is insoluble in water, while Dr. Franz Fischer (Bronn, Verflüssigtes Ammoniak als Lösungsmittel, page 226) gives the solubility of naphthalene in pure liquid ammonia as being very slight. The experiments described by the author did not confirm these statements as to the solubility of naphthalene.

Experiments were made at 0 deg. and 25 deg. C. Three hundred grams of ammonia water of 5, 10 and 25 per cent strengths were agitated with 2 gr. of naphthalene for 15 hours at 25 deg. C. and then filtered. The determinations at 0 deg. were made in ice for 12 hours. The naphthalene was determined by neutralizing the ammonia with sulphuric acid, the naphthalene separating out, and being forced over with steam. The naphthalene is then dissolved in ether, a known amount of picric acid added, the ether distilled off, and the excess acid titrated with standard caustic. The method takes only about ½ hr.

The results of the solubility tests of naphthalene are given in the following table. The results are given as grams of naphthalene soluble in 1000 gr. of solution:

Per Cent NH_3	Solubility	
	0°	25°
0	0.019	0.030
5	0.030	0.044
10	0.042	0.074
25	0.064	0.162
100	33.	120.

In practice the components are not so pure, consequently the addition of 2 per cent pyridine was tried, which raised the solubility at 0 deg. to 0.082 and at 25 deg. to 0.245. Phenol was also tried and it was found to have little effect. Carbonic acid or hydrogen sulphide when present have a much greater effect, but a quantitative test was not made.

Experiments were made to determine the proportions of naphthalene and ammonia coming over upon distilling an ammoniacal solution. The vapors showed a changing proportion of naphthalene to ammonia, as in the solutions. They are richer in naphthalene the higher the temperature of distillation. On the other hand the proportion is lower than required by the partial pressure of the naphthalene at the distillation temperature. In general it is advisable to keep the temperature of the conducting columns above 30 deg.

Chemical Theory

Transmutation of Chemical Elements.—Some interesting experiments on radioactivity, with a view to inducing it in other substances are described in the *Zeit. für Phys. Chemie*, vol. 90, page 557 (1916), vol. 89, page 151 (1915), and Dec., 1914, by W. P. JORISSEN and J. A. VOLLGRAF of the University of Leiden, and abstracted in London *Engineering*, May 12, 1916. The authors first tried uranium oxide (U_3O_8), which was placed in a dish of Jena glass on an anode of platinum, the cathode of their bulb being of aluminium; currents of up to 4 milliamperes were used, the gas pressure in the bulb being below 0.05 mm. There was no visible change apart from a colour change, the grey oxide turning black; the grey colour could be restored by heating the oxide in oxygen, and it is very probable that the U_3O_8 had given off some oxygen under the cathode-ray bombardment. But the radioactivity of the oxide, as tested by the electroscope, was not changed, and that had been the chief object of the experiment. The investigators then took bismuth. P. Villard had observed in 1900 that bismuth was photographically active after bombardment; he did not state, however, whether there had not been any activity before the bombardment, and Jorissen and Ringer had not been able to confirm his observation in 1907. For the new experiments they placed the powdered bismuth again in a glass dish; the glass broke, however, and the bismuth fused, evaporated, and formed a bismuth mirror on the wall of the bulb. The glass was then replaced by quartz. The treatment did not render the bismuth at all radioactive, nor did the metal act on a photographic plate, as Villard had stated. The chemical analysis by Schoorl showed that the original bismuth had not contained any thallium; traces of calcium and also of potassium and sodium were, however, found in the bismuth mirrors, and these metals were probably due to a contamination by the glass of the bulb. These chemical analyses were supplemented by spectroscopic tests, and then a trace of thallium was discovered in the untreated bismuth; the thallium lines were faint, however, and were not any stronger in the treated metal than in the untreated metal. The presence of these traces of thallium is not surprising. Herapath proved in 1863 that thallium is a frequent companion of bismuth, and this was confirmed by Sir W. Crookes, the discoverer of thallium. The reasons for the search for thallium is that the atomic weight of bismuth is 208 and that of thallium 204; the two atomic weights thus differ by 4, which is the atomic weight of helium. The idea was that the cathode-ray bombardment might expel an α ray (a helium atom) from the bismuth. It may be objected, however, that the treatment only lasted a few periods of four hours or less. Radioactive phenomena, it is known, are not affected by the ordinary changes in temperature, pressure, etc., producible in the laboratory; extraordinary violence might have effects. It might also be mentioned that the atomic weight of bismuth was some years ago supposed to be 208.5, and that some chemists again favor this value, while the international tables give the weight as 208.0.

Copper

Allotropy of Copper.—In the *Journal* of the Washington Academy of Sciences, Dec. 19, 1915, Messrs. G. K. BURGESS and I. N. KELLBERG give the results of some experiments made at the Bureau of Standards on the allotropy of copper. According to the work of Prof. E. Cohen (see this journal, Sept. 1, 1915, p. 536) copper has a transition point between 69.2 deg. C. and 71.7 deg. C. under varying conditions of fineness and previous contact with an electrolyte. The authors made a series of experiments by an electric resistance method, in the range 0 to 100 deg. C. The results were negative, i. e., they failed to find any transition points in this range.

The copper used was in the form of hard drawn wire 0.005 cm. diameter by 35 cm. long, wound, together with a platinum wire of 0.015 cm. diameter, on a mica frame and inclosed in a glass tube. This was immersed in a completely waterjacketed and electrically controlled calorimeter, the temperature of which could be made to vary uniformly between 0 and 95 deg. C.

Three methods of measurement were used, as shown in the illustration.

1. The resistance of the Pt and Cu coils was measured differentially, and simultaneous observations of temperature were taken with a mercury thermometer.

2. Using the same coils, a commutator was inserted which permitted taking alternate readings of Pt resistance, which then served as a thermometer, and of the Pt-Cu resistance difference.

3. The Pt and Cu resistances were measured separately with a common lead and a common battery lead and the times taken to 0.1 second on a chronograph. The thermometer leads were of gold for the third series and

of copper for the other two. When examined microscopically the copper showed only a small quantity of cuprous oxide inclusions.

The results of the measurements showed that the resistance of the copper varied continuously from 0 to 100 deg. C., and that it was probably not in a metastable state.

Coke

The Sulphur Content of Coke.—In a paper presented at the New York meeting of the American Institute of Mining Engineers, February, 1916, Mr. J. R. CAMPBELL describes the effect of aeration and quenching on the sulphur content of coke. Sulphur is known to exist in coal as sulphides, sulphates, and as organic sulphur. For most coking coals the greater part of the sulphur can be safely assumed to be in the form of pyrite FeS_2. When exposed to the low temperatures in the coking process one or both of the following reactions take place:

$$7\,FeS_2 = Fe_7S_8 + 6\,S$$
$$FeS_2 = FeS + S$$

The first equation gives the magnetic pyrrhotite and sulphur, while the second, which is the more commonly accepted one, gives straight iron sulphide and sulphur.

In the beehive method, air is introduced in sufficient amounts to carry on the distilling and coking processes, and the sulphur is oxidized, along with the other volatile products. For coals of about 30 per cent volatile matter the ratio of air to gas is 3½ to 1, so that a low grade producer gas issues from the trunnel head. The sulphur remaining in the coking mass as iron sulphide cannot in any way be affected by the aeration or draft on the oven. The old saying common among beehive oven operators, "the hotter the oven the more sulphur burned out" probably never was true unless aeration was carried to complete combustion of not only the gases but the fixed carbon itself, in which case the iron sulphide would be oxidized to Fe_2O_3. This would give an abnormally low yield of coke. As far as pyritic sulphur is concerned no amount of superaeration will produce increased elimination of sulphur at the low temperatures of distillation. If coking proceeds too quickly or if the heat is irregular, the desulphurization is apt to be less complete, due to the formation of compounds on which heat has no effect.

In the by-product oven no air is supplied and as good an elimination of the sulphur is obtained. This shows the fallacy of superaerating beehive ovens. Sulphur existing in sulphates and as organic sulphur is likewise not affected by aeration.

Quenching should theoretically remove considerable sulphur, but it has been the author's experience that very little was removed in this manner. According to the equation $FeS + H_2O = FeO + H_2S$, sulphur should be eliminated, and the odor of H_2S is noticed, but the coke mass cools very quickly, and its structure prevents the rapid penetration of the water, and as the temperature is lowered the reaction slows up. Quenching is essentially a cooling process.

Hydrochloric acid, when added to the water, greatly facilitates the removal of sulphur, as it readily attacks iron sulphide. This is a fact not generally known. The cost has usually prohibited this method, but with the low-sulphur coking coals disappearing this method may become important.

The C. W. Hunt Company, Inc., West New Brighton, N. Y., has issued a new valve catalog No. 15-3. This catalog contains illustrations and descriptions of its standard types of gates and valves for controlling the flow of bulk materials, such as coal, ashes, coke, ore, stone, sand, gravel, etc.

Recent Chemical and Metallurgical Patents

Electric Furnaces

Electric Furnace for Making Graphite.—An electric graphite furnace which is designed to effect heat savings by preheating the coke charge is patented by JOHN W. BROWN, of Lakewood, Ohio, and assigned to the National Carbon Co., of Cleveland, Ohio. The furnace is a continuous one, the coke charge being fed into the top by a screw conveyor and removed at the bottom by the same means. One form of the furnace is shown in Fig. 1.

The furnace walls are made so as to contain a hollow space, 7, connecting with the charge, at the top of the

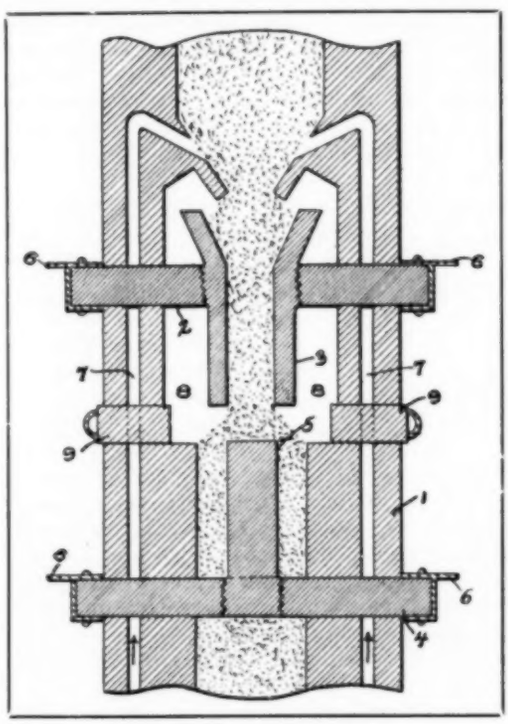


FIG. 1—GRAPHITE FURNACE

furnace. Air or an inert gas is led into the hollow space at the bottom, and is heated by the finished charge which it cools. The gas then goes to the top of the furnace, where it preheats the charge, and emerges in a practically cool state. If air is used, a part of the charge will burn, thereby heating it up considerably, but not enough to graphitize it. The central zone, 3, of the furnace is made of carbon and is connected to electrodes, 6, which furnish the heat necessary to graphitize the carbon. The bottom electrode is shown at 5. The carbon and the coke at the central zone together form the resistor. Several different ways of preheating the charge are mentioned, as follows: By the combustion of a part of the charge itself, by inert gases, by gases passed both through the charge and the walls, by burning hot gases in the upper part of the furnace, and by combinations of these methods. A space just below the central heating zone is provided in which volatile matter can condense, and it is removed through an opening in the side of the furnace from time to time. (1,177,680, Apr. 4, 1916.)

Electric Heat-Treating Furnace.—An electrical resistance furnace for heat treating is patented by T. F. BAILEY and F. T. COPE, of Alliance, Ohio, and assigned to The Electric Furnace Company of Alliance, Ohio. In this furnace the heat from granular carbon resistance elements is reflected from an arched roof down onto the

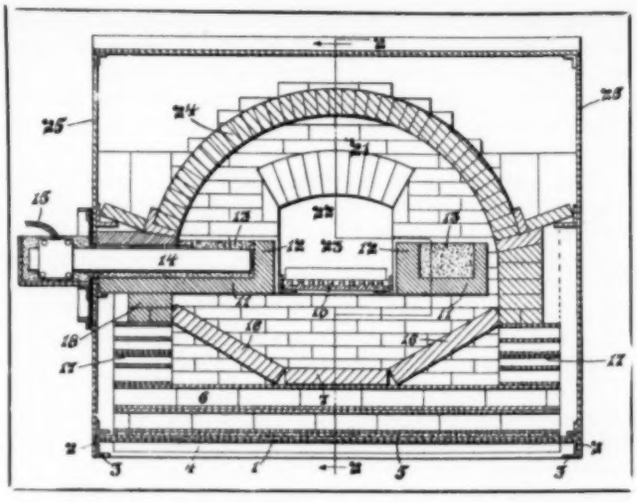


FIG. 2—ELECTRIC HEAT-TREATMENT FURNACE

hearth which contains the material to be heated. A cross-section of the furnace is shown in Fig. 2. The outer casing is of metal and the inner furnace structure is of brick. Extending the length of the furnace and on each side of the middle space, 23, are troughs, 12, containing granular coke or charcoal. Electrodes, 14, are placed at each end of these resistance elements. The heat from the carbon rises and strikes the arched roof, from which it is reflected down onto the hearth. Inclined walls, 16, are also located below the resistance elements in order to reflect the heat which is radiated downward back to the hearth. (1,176,018, Mar. 21, 1916.)

Roasting or Sintering Apparatus Using Electric Heating.—A continuous apparatus for roasting or sintering ores working on the down-draft principle and with "electric firing" is patented by WILLIAM H. HAMPTON, of New York City (assigned to the Conley Electric Furnace Company, Inc., of Wilmington, Del.) The ore or ore mixture is fed from bins into an endless chain conveyor composed of box or trough-like sections hinged together and perforated at the bottom. The ore is then transported along a straight or curved path to a point of discharge. During their course the sections pass over a suction arrangement, which consists of a compartment beneath the conveyor, connected to a suction pump. The top of the compartment is perforated. Above this compartment and above the conveyor is a heating compartment containing electrical resistances. Air passes into this heating compartment, is heated and then passes down through the ore by the suction which causes the down-draft. The heating resistances are made of 60 per cent clay and 40 per cent carbon. If the ore contains sufficient combustible material to need only initial ignition, thereafter burning itself, it can easily be treated by this method. The air necessary to continue the combustion can be supplied from an adjacent compartment either as cold or hot air. If the operation is not to be a sintering one, agitation may be used. It is claimed that ores with less sulphur content than ordinarily used can be roasted and sintered, and that in cases where fuel is needed, less will be used with this process. (1,171,117, Feb. 8, 1916.)

Nitric Acid from Air

Nitrogen Fixation Process.—A boiler having a nitrogen fixation furnace placed inside and integral with it, in order to utilize the excess heat either in the generation of steam, or in the evaporation of solutions, is patented by HANS SCHEFTLEIN, of Christiania, Norway (assigned to Norsk Hydroelektrisk Kvaelstofaktieselskab, of Christiania, Norway). This apparatus is claimed to avoid the drawbacks of previous systems for utilizing the heat of the gases issuing from nitrogen furnaces. In some of these systems the gases have been conducted through boiler plants, but the large cost of installation and the relatively large space required, as well as the losses of heat caused by the passage of the gases through pipes or channels have reduced the efficiency of these systems considerably. In the present process it is proposed to place several nitrogen furnaces (Schoenherr type) in separate flues in a vertical boiler, so that the nitrogen furnace replaces the firebox. (1,180,545, April 25, 1916.)

Ozone

Treating Oils, Greases and Fats with Ozone.—An apparatus for treating oils, or liquefied greases and fats with nascent ozone is patented by ALBERT BREYDEL, of Brussels, Belgium. The apparatus consists of a rectangular vessel, holding the oil, or other liquid to be treated. At the bottom of the vessel an electrode is held between two dielectric plates. A short distance above it is placed another electrode made of hollow material, not subject to attack by ozone, and containing small perforations. Air or oxygen is forced through this upper electrode, and, passing through the perforations, ozone is formed at the surface of the upper electrode. This system is claimed to give a good circulation and to work at any temperature without a cooling medium being required. (1,180,372, April 25, 1916.)

Zinc and Lead

Process of Briquetting Zinc Ores and Waste Products.—The preparation of finely divided zinc ores, zinc dust, ash, trimmings and other forms of waste material containing zinc, for treatment in electric or retort furnaces, is patented by OTTO KIPPE, of Osnabrück, Germany. The materials mentioned are briquetted with from ¼ to 2 per cent of a soluble salt, such as the chloride or sulphate of magnesium, calcium, iron or zinc. The briquets thus formed are coherent and hard, and are ready for smelting in a short time. (1,168,401, Jan. 18, 1916.)

A special form of briquet for zinc ores, particularly suited to retort distillation, is patented by OTTO BALTIN, of Lipine, Germany. The ore and reducing agent are formed into egg-shaped briquets which are so small that the sum of their exposed surface is many times that of the receptacle used in distillation. When charged into a retort these briquets have only one point of contact with each other, and expose practically their entire surface to the direction action of heat. Ample space is left between them for the easy escape of zinc vapors. (1,166,170, Dec. 28, 1916.)

Treatment of Zinc Ore in Electric Furnaces.—A difficulty encountered in treating an ore charge in an electric furnace is the formation of crusts of slag or other material in the proximity of the tap-hole. In order to obviate this trouble, EDWARD S. BERGLUND, of Trollhättan, Sweden, proposes to add to the furnace at intervals certain easily fusible materials that will combine with the melt and stiff crusts. Thus in the case of zinc ore he adds 200 kg. of fluorspar to a charge of 1000 kg. of ore and carbon, mixing them intimately before charging; or he may add such fluxes as fluorspar, lime and old slag just before the furnace is tapped, introducing the substances in proximity to the tap-hole. (1,160,244, Nov. 16, 1915.)

Refining Leady Matte.—The customary manner of handling leady matte is to blow off the lead and other volatile impurities in a converter and catch the volatile

products in a bag-house. This method entails further treatment of the bag-house product for recovery of lead. According to a patent granted to N. V. HYBINETTE of Christiania, Norway, a simpler process can be devised, yielding metallic lead and copper from the matte, the lead containing also the precious metals. The process is illustrated diagrammatically in Fig. 3.

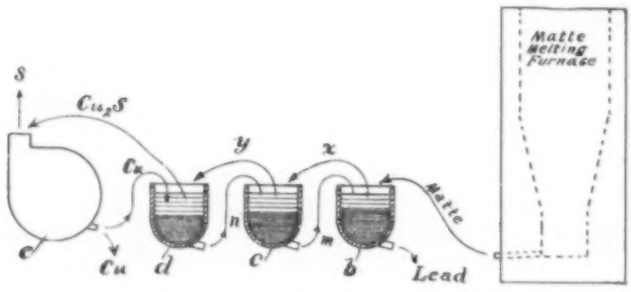


FIG. 3—REFINING LEADY MATTE

The molten matte is treated on the counter-current principle with copper produced in a converter, the effect of the pure copper being to separate a bottom of metallic lead from the matte. The latter successively loses its content of lead and takes up the equivalent amount of copper from the bottom. Thus in Fig. 3 the matte follows the direction indicated by the arrows x and y, and the refined material in the reverse direction as indicated by arrows n and m. Lead is withdrawn at the point where fresh leady matte enters the system and refined matte leaves at the opposite end for converting and the return of a part of the copper. (1,175,266, March 14, 1916.)

Miscellaneous and Rare Metals

Separation of Cobalt from Ores.—A method of recovering cobalt from ores and materials containing a large quantity of arsenic is patented by PHILIP M. MCKENNA, of Washington, D. C. The raw material is first smelted to produce a speiss containing cobalt, nickel, etc. A typical speiss may contain 22.4 per cent Co, 13.9 per cent Ni, 10.6 per cent Fe, 45 per cent As, 3.6 per cent Sb. The speiss is then ground to 60-mesh and roasted in a furnace with alternately oxidizing and reducing atmospheres, at a temperature low enough to prevent agglomeration. Arsenic will be reduced to from 8 to 23 per cent. The next step consists in fusing the roasted speiss with boron trioxide, whereupon the cobalt combines with the boron in much greater percentage than does nickel, with the result that a gravity separation of the molten nickel arsenide speiss and boric cobalt slag can be effected. The boric mass is then treated in a separate furnace to expel traces of arsenic or antimony, after which it is charged into an electric furnace with carbon. Cobalt, with some iron, is reduced and forms the finished product. If iron is undesirable the speiss should be freed from that element by melting with silica before roasting. (1,166,067, Dec. 28, 1915.)

Tungsten for Catalytic Ammonia.—A process of producing amorphous tungsten suitable for use as a catalyzer in the synthetic production of ammonia is disclosed in a patent granted to CARL BOSCH and ALWIN MITTASCH of Ludwigshafen-on-the-Rhine, Germany. The patent is assigned to the Badische Anilin & Soda Fabrik of the same place. The method consists in reducing tungstic acid or ammonium tungstate with hydrogen at a temperature not exceeding 600 deg. C. and under a pressure of not less than 10 atmospheres. A modified procedure consists in treating similar material directly in the contact tube with nitrogen and hydrogen at the same temperature and pressure. In the latter method the tungstic acid is first reduced to metal or a nitride, whereupon the formation of ammonia commences and continues. In two examples cited in the specifications the temperature ranges from 550 to 600 deg. and the pressure from 80 to 150 atmospheres. (1,175,693, March 14, 1916.)

The separation of thallium and other radioactive metals from lead ores, and the production of a white-lead pigment is patented by JAMES B. HANNAY of Hamburg, Germany. If galena is rapidly vaporized in an atmosphere of hot reducing gases, such as carbon dioxide and nitrogen, and the vapor is oxidized by the addition of a large excess of air as near as possible to the outlet of the furnace, and if the fumes be allowed to cool comparatively slowly, the salts of thallium and the radioactive metals form a mixture with the lead sulphate having a lower melting point than lead sulphate. As a consequence they remain longer in the liquid state and tend to coalesce in large drops that fall in the first collecting chambers, while lead sulphate is carried farther. The volatilization of the deposited fumes may be repeated to obtain a further concentration of thallium and the other metals. (1,175,146, March 14, 1916.)

Flotation Oils*

BY O. C. RALSTON

The sudden development of the art of flotation has brought about peculiar conditions in the oil market. A few years ago there was considerable expansion in the wood-distilling industry throughout the South on the hope of selling turpentine at not less than 50 cents per gallon. This hope was never realized and the industry became demoralized owing to excessive production and the efforts of some plants to keep going even at a loss. Pine oil, which previously has had little sale, is a by-product from this industry and has been found one of the best of oils for flotation purposes. At the time of the introduction of the flotation process into the country a stock of pine oil that had accumulated was for sale at an attractive figure.

This supply of pine oil and its derivatives has been largely exhausted and we are having to depend upon current production for the present supply. Hence the price has soared, and some of the pine oil on the market has been adulterated. Pine oil is also proving to be a valuable antiseptic and it is doubtful whether it will ever again be sold cheaply. Furthermore, turpentine is now about 50 cents per gallon and the fractionation of the wood distillate is being made in favor of a high yield of turpentine.

During 1915 the principal investigation in connection with the flotation oils was conducted for the purpose of finding a substitute for pine oil now costly. Most of the wood creosotes have proved acceptable and are now being sold at lower prices than the pine oils. How long this condition will continue is a matter of conjecture. The creosotes have proved to be good preservatives of wood, especially of railroad ties. However coal creosotes excell wood creosotes for preserving timber, so that flotation will probably cause most of the wood creosote to be diverted from timber preservation. Further, the starting of many large flotation mills during the coming year, and the enlargement of many that have been operating in an experimental way, may create such a demand for wood creosote that the cost of this oil may equal that of pine oil.

In view of such a possibility, considerable work has been done to determine whether coal tar and coal tar creosote could not be successfully used as flotation oils.

*A statement issued by the Department of the Interior, Bureau of Mines (Van H. Manning, Director).

In many instances it was possible to do so only after adding a small amount of one of the true wood oils. There is some difficulty in getting the thick heavy coal tar to mix well with the pulp, so that it is not the most desirable medium, and for that reason the coal creosotes have met with more favor. Consequently, most of the gas plants throughout the country have been able to contract for their output of creosote for some time to come. A similar condition prevails with regard to most of the wood oils. There has been somewhat of a rush in the mining industry for contracts for these products in order that proposed mills will be assured of being able to operate. When Germany gets into the coal creosote market again there will doubtless be lower prices for that particular product.

The petroleum men have not been slow to seek the flotation oil market, but their products have not as yet met with much success when used alone. It is possible to mix small amounts of pine oil or creosote with various petroleum products such as stove oil and to obtain flotation with some degree of success, but the general tendency of petroleum products is to float both gangue and mineral non-selectively. The petroleum products that have met with the most success are some of the crude oils, such as Texas crude, and especially certain high-sulphur crude petroleums, obtainable in Kansas and in California. "Stove oil" has met with some success in the copper-concentrating mills, as copper minerals do not have to be concentrated to the same degree of purity as do the lead and zinc minerals. It is probable that, for the wood oils, the copper mills will be able to use cheaper substitutes, such as petroleum products, than will the mills treating baser metals.

One other product that has met success has been the "kerosene acid sludge" from certain of the petroleum refineries. This material is the resultant of the removal of certain impurities with sulphuric acid and often consists of as much as 50 per cent sulphuric acid. Not all of the acid sludge products have proven suitable, only the California sludge being sold at present.

Just how far all this substitution will be successful is not known and there is no way to predict. The test work of the coming year should go far toward solving this problem.

PRODUCERS OF OILS MORE OR LESS ADAPTED TO FLOTATION

Following is a list of dealers in different oils who have placed on the market various products. A host of these dealers are prepared to supply these products at any time, and of fairly uniform quality. None of them has been able to exactly duplicate their carload shipments, so that the general practice is to test each shipment of oil in a laboratory testing device to determine the proper method of using a given shipment of oil. This non-uniformity of shipments will doubtless vanish when the market becomes steady.

Wood Oils

Pine oils, rosin oils, wood creosotes, tar oils, turpentines, etc.:

1. Pensacola Tar & Turpentine Co., Gull Point, Fla.
2. General Naval Stores Co., New York.
3. Georgia Pine & Turpentine Co., 158 Perry Street, New York.
4. Central Distilling Co., Helena, Ark.
5. United Naval Stores Co., Helena, N. Y.
6. American Tar & Turpentine Co., New Orleans, La.
7. Cleveland Cliffs Iron Co., Cleveland, Ohio.
8. Chesapeake Tar & Rosin Co., Baltimore, Md.
9. Custer City Chemical Co., Custer City, Pa.
10. Yaryan Naval Stores Co., Brunswick, Ga.
11. Hussay & O'Connel, Savannah, Ga.
12. Florida Wood Products Co., Jacksonville, Fla.
13. Oregon Wood Distilling Co., Portland, Ore.
14. National Wood Products Co., Wilmington, N. C.
15. Chapman Manufacturing Co., Savannah, Ga.
16. Spiritine Chemical Co., Wilmington, N. C.

Eucalyptus oil:

17. Atkins, Kroll & Co., San Francisco, Cal.

And other importers.

Coal Tar, Coal Creosotes, and Aromatic Hydrocarbons

1. The Barrett Co., New York.
2. F. J. Lewis Manufacturing Co., Chicago, Ill.
3. American Creosoting Co., New Orleans, La.
4. American Tar Products Co., Chicago, Ill., and St. Louis, Mo.
5. Republic Creosoting Co., Indianapolis, Ind., and Minneapolis, Minn.
6. American Coal Refining Co., Denver, Col.
7. Numerous municipal and similar coal-gas plants.
8. Numerous by-product coke ovens, such as:

Pennsylvania Steel Co., Steelton, Pa.
National Tube Co., Penwood, W. Va.
Milwaukee Coke & Gas Co., Milwaukee, Wis.
Pennsylvania Steel Co., Lebanon, Pa.
Solvay Process Co., Syracuse, N. Y.
By-Products Coke Corporation, South Chicago, Ill.
Semet-Solvay Co., Detroit, Mich.
Central Iron & Coal Co., Tuscaloosa, Ala.
New England Gas & Coke Co., Everett, Mass.
Illinois Steel Co., Joliet, Ill.
Maryland Steel Co., Sparrows Point, Md.

Vegetable Oils

1. Cottonseed oil, etc.—Southern Cottonseed Oil Co., New York.
2. Corn oil—Corn Products Company, New York.
3. Palm oil—Peter van Schaack & Co., Chicago, Ill.

Animal Oils (Fatty Acids)

1. Oleic acid—Peter van Schaack & Co., Chicago, Ill.
2. Oil flotation grease emulsion—Mohawk Refining Co., Cleveland, Ohio.

Petroleum Products (Crude, Asphaltum Base)

1. California crude—Union Oil Co., Santa Paula, Cal.
   Association Oil Co., Los Angeles, Cal.
   Standard Oil Co., Richmond, Cal.
2. Road Oil No. 80—Harris Oil Co., Los Angeles, Cal.

Reconstructed Petroleum Oils

1. Special mineral separator—Continental Oil Co., Salt Lake City, Utah.
2. Solulene and minolene—Star Lubricating Co., Salt Lake City, Utah.

Refined Petroleum Products

1. Stove oil—Standard Oil Co., San Francisco, Cal.
2. Stanolind, etc.—Continental Oil Co., Salt Lake City, Utah.
3. Flotation oils—Utah Oil Refining Co., Salt Lake City, Utah.
4. Heavy mineral flotation oils—Geo. P. Jones & Co., St. Louis, Mo.
5. Refinery acid sludge—Any refinery.
6. Lubricating oils—Any company.

Special Mixtures of Mineral and Wood Oils

1. Calol oils—Standard Oil Co., Richmond, Cal.
2. Mine & Smelter Supply Co., Denver, Col.
3. Hendrie & Bolthoff Manufacturing & Supply Co., Denver, Col.

Costs of Flotation Oils

The costs of flotation oils have varied so much, owing to the unsettled market, that it is almost impossible to give an idea of what they should cost. For a rough estimate it is possible to say that crude petroleum will cost the same as for other purposes. Many of the

dent of the International Nickel Company, representatives of the Société de l'Air Liquide of France, and Walter W. Birge of St. Louis, who is the present active head of the company.

Mr. Birge says that the company will concentrate its efforts first on oxygen, which is a big field, especially in oxy-acetylene use. The company has engineers in Europe investigating the calcium carbide situation with a view to manufacturing this commodity, probably in Europe, for making acetylene for use in the oxy-acetylene burner for welding and cutting. The company may also make compressed acetylene, if they take up the carbide manufacture.

Another important field which the company will enter, after having the oxygen business thoroughly organized, is the production of nitrogen, cyanamid, ammonia nitrates and nitric acid. Two or three processes for making nitric acid are being tried out at the present time and the experiments are well under way. The South is a big field for fertilizer and the company expects to establish nitrate manufacture in the South either by one central plant or several distributed plants.

It is expected that the capital stock will shortly be considerably increased.

A New Foundry Equipment Firm

Leyshon & Lane, Inc., has recently been organized to take over the oven and special foundry equipment business which has grown out of Mr. H. M. Lane's foundry research work.

The H. M. Lane Company was organized several years ago to do foundry consulting engineering work, to design new foundries, or to plan improvements for old foundries. It was not the intention that this company should become a contracting or manufacturing organization, but in connection with the betterment work carried on in foundries, various devices were required and special equipment needed which could not be obtained on the market. Some of these have been taken over by regular manufacturers, and some of them were patented by H. M. Lane, particularly the forced draft core and mold oven system.

One installation has sold another until a considerable business has grown out of this line, and recognizing the field, Leyshon & Lane, Inc., has been organized to contract for complete foundry installations, to install melting furnaces, annealing ovens, core ovens, mold ovens and handling appliances. Mr. T. A. Leyshon, who has been associated with Mr. H. M. Lane for several years, is president of the new organization; and Mr. C. T. Holcroft, who has been in the furnace building business for many years, first in the Chester, Pa., district, next in the Pittsburgh district, and later in Detroit, is treasurer. The new company has made arrangements for a portion of Mr. Lane's time so that he can act as consulting engineer on any problems they may have.

The H. M. Lane Company will continue as a consulting organization under the personal charge of Mr. H. M. Lane. The organization of the new company will free Mr. Lane of direct responsibility for the oven business and give him more time for consulting practice.

Personal

Mr. **L. G. E. Bignell,** formerly sales manager for the Denver Engineering Works and for the past three years engineer for the Mine & Smelter Supply Company at El Paso, has accepted a position with the Colorado Iron Works at Denver as sales engineer, and assumed his new duties June 1.

Dr. **Charles Blanc,** expert organic chemist, has become connected with Messrs. Moses, Pope & Messer of 366 Fifth Avenue, New York City, in the capacity of a consulting chemist.

Mr. **N. C. Harrison,** formerly steam engineer at the Pittsburgh Crucible Steel Company, has been made general superintendent of the Atlantic Steel Company, Atlanta, Ga.

Mr. **Weston B. Lazear** has recently assumed charge of the New York office of the Stephens-Adamson Company. Mr. Lazear has devoted the past seven years to the design of "S-A" conveying, elevating, screening and transmission machinery. Various stages of his experience cover a period as draftsman, then chief draftsman, and later sales engineer. In the latter capacity he has been associated with the New York office for the past year.

Mr. **S. Naganuma** has opened an office in the Equitable Building, 120 Broadway, New York, as representative of Mitsubishi Goshi Karsha, mining and shipping firm of Japan.

Dr. **J. F. Norris,** of the department of chemistry at Vanderbilt University, has accepted an offer from the Massachusetts Institute of Technology to take charge of research work and applied chemistry with fifth-year students in the new chemical engineering course which starts next fall. Dr. Norris formerly taught for five years at the Institute. He was recently appointed by Secretary of the Navy Daniels as one of the members of the Tennessee State Board of Industrial Organization for Preparedness.

Mr. **Stanley H. Rose,** until recently in charge of the New York office of the Bureau of Foreign and Domestic Commerce of the Department of Commerce, has been engaged by the Barber Asphalt Paving Company to direct its foreign trade department. Prior to his appointment as commercial agent of the bureau Mr. Rose had had an extensive business experience in the larger part of Europe, Australia, New Zealand, India and Egypt, and has also held important posts with American and European firms engaged in foreign trade. He is considered an expert in foreign tariffs, trade regulations and shipping. As special agent of the Bureau of Foreign and Domestic Commerce, Mr. Rose has just completed a tour of more than fifty cities of the Middle West, South and Southwest, acquainting manufacturers with foreign trade opportunities and advising commercial organizations as to the best methods of promoting export trade. Mr. Rose was educated in London, Berlin, Paris and Brussels, and speaks most of the modern languages.

Mr. **Lyon Smith,** formerly metallurgist of the Pittsburgh-Silver Peak Gold Mining Company, has been appointed metallurgist for the Snyder Electric Furnace Company of Chicago.

Mr. **G. H. Stephens,** until recently vice-president and Eastern manager of Stephens-Adamson Manufacturing Company, has retired from active business on account of ill health. Mr. Stephens has been prominent in the conveying industry for twenty-five years, and has enjoyed a wide acquaintance among machinery users of the East.

Obituary

John Edson Sweet, president of the Straight Line Engine Company, Syracuse, N. Y., and for several years professor of mechanical engineering at Cornell University, died at his home in Syracuse, on May 8. He was best known as a founder of The American Society of Mechanical Engineers and designer of straight line engines. He was born in Pompey, N. Y. on October 21, 1832, and received most of his early education in the

district schools. Up until 1872 he worked in various mechanical lines, mostly in railroad shopwork and draughting. He also spent some time in England and France, and in 1871 and 1872 designed his first straight line engine. In 1873 he took up teaching work at Cornell, which he continued until 1879. He was instrumental in organizing the American Society of Mechanical Engineers in 1880, of which he was president in 1883-4. He was the recipient of the John Fritz medal in 1914 (see our vol. XIII, p. 75) and in 1914 received the degree of Doctor of Engineering from Syracuse University. He was also a member of the Advisory Board of the New York State Branch, National Society for the Promotion of Industrial Education.

Mr. **George M. Kendall,** for a number of years manager of the New York office of the Pfaudler Company and widely known among the chemical and pharmaceutical trades, died on Monday, May 22, at the home of his father in Ludlow, Vt. Mr. Kendall had suffered for more than a year from a complication of diseases, which caused his death, and his inability to engage actively in the service of the firm with which he had so long been connected was a sore trial to him. He was an exceptionally energetic and aggressive worker, firm in his convictions, and guided in all his dealings by a strict "New England conscience." Even while confined to his bed, he continued to keep in touch with his office, and to inject his forceful personality into its activities.

Industrial Notes

New Evaporating Plant.—The new evaporating plant installed by the Penobscot Chemical Fibre Company at Great Works, Me., has been working very satisfactorily. The builders of this apparatus advise that it contains improvements in the methods of handling caustic soda from electrolytic cells and has been designed for the special purpose of operating in conjunction with the Larchar cell. The Swenson Evaporator Company built and installed these evaporators, and after successfully operating same secured a contract for a new large quadruple effect for the soda recovery system.

The Hoskins Manufacturing Company, Detroit, Mich., due to the increasing demand for Hoskins electric furnaces, pyrometers, hot plates, and chromel resistor material, has opened a branch office in Boston at 613 Equity Building, 185 Devonshire Street, in charge of Mr. J. E. Hines. This is the third branch office the Hoskins company has opened in the East. Other branches are being maintained at 3709 Grand Central Terminal, New York, in charge of F. L. Zimmerman; 1404 Oliver Building, Pittsburgh, in charge of W. C. Tharp, and 1610 Otis Building, Chicago, in charge of C. F. Busse.

Balances.—The various American makers of assay balances have developed their methods of manufacture to the point that their product for the exacting conditions of use in the assay office far excels that of European makers, who are less familiar with the special requirements of the assayer. As illustrating, in one case, the careful work done, the G. P. Keller Manufacturing Company of Salt Lake City exhibited a set of standard assay weights at the Panama-Pacific International Exposition which the Bureau of Standards certified to as follows:

Weight	Correction	Weight	Correction
500 mg.	—0.001 mg.	10 mg.	—0.001 mg.
200 mg.	0.000 mg.	10 mg.	—0.001 mg.
100 mg.	+0.003 mg.	5 mg.	0.000 mg.
100 mg.	0.000 mg.	2 mg.	0.000 mg.
50 mg.	—0.002 mg.	2 mg.	—0.002 mg.
20 mg.	—0.001 mg.	1 mg.	—0.001 mg.

Reduced Production of Turpentine and Rosin.—The preliminary statement issued by the United States Bureau of the Census of the 1914 census of manufactures with reference to the turpentine and rosin industry in this country shows that the production during 1914 was considerably less than during 1909, according to Commerce Reports. Reports were received from 1392 turpentine distilleries. Their total output was valued at $20,968,684 and consisted of 26,980,981 gal. of spirits of turpentine, valued at $10,510,407; 2,885,077 barrels of rosin, valued at $10,332,700, and dross, valued at $125,577. The census of 1909 gave reports from 1585 distilleries, and their total production was valued at $25,295,017, about evenly divided between spirits of turpentine and rosin. The figures for 1914, including besides those mentioned the products of lumber manufacturing and wood-distillation plants, compared with the amounts for 1909, show decreases of 16.1 per cent in total value, 6.9 per cent in quantity of spirits, 16.8 per cent in value of spirits, 9.8 per cent in quantity of rosin, and 15.9 per cent in value of rosin, and an increase of 96.3 per cent in value of dross.

The Trill Indicator Company of Corry, Pa., has issued a new 56-page publication on engine indicators and indicating. The book is instructively illustrated and describes in detail the construction and purpose of the several parts of both the outside and inclosed spring types of indicators, including indicator reducing motion. Considerable space is given to discussion and data on indicator springs, and full instructions on indicating and interpreting cards from all types of engines, high-pressure steam, gas and fuel oil engines, triple-expansion and compound engines, and ammonia compressors. Detailed instructions are given on the application and use of the indicator and the planimeter, with easily understandable instruction on the few arithmetical calculations that are necessary. There are fifteen pages illustrating and discussing the characteristic diagrams of the several types of engines including the latest four-valve engines of the new Poppet Valve type, the Uniflow engine, high-compression two-cycle oil engine, and the Diesel engine; also a large number of faulty diagrams illustrating the characteristic faults of engines.

The Ha Ha Baie Sulphite Company of Chicoutimi, Province of Quebec, Canada, has announced the awarding of the contract for the construction of its new paper pulp plant at Bagotville, Chicoutimi County, Province of Quebec, Canada, to the J. G. White Engineering Company of New York, under the direction and design of Mr. Hardy S. Ferguson, paper mill engineer, also of New York. This plant, which marks a decided step in the pulp manufacturing activities of northeastern Canada, will embody the latest improvements in design, and the initial installation will have a capacity of 120 tons of sulphite pulp per day. The mill buildings, of brick, concrete and steel, will be erected on the shores of Ha Ha Bay, on the Saguenay River, and will occupy a space of approximately 5 acres, and besides the usual rail facilities will be provided with a system of wharves, accommodating ocean-going vessels. Work at the site has begun, and it is expected that the plant will be producing pulp early in 1917. Mr. J. E. A. Dubuc, president of the North American Pulp & Paper Company and general manager of the Chicoutimi Pulp & Paper Company, will be at the head of this new enterprise.

Humidifying.—Bulletin No. 100 entitled "Carrier Humidifying Apparatus," has just been published by the Carrier Engineering Corporation, 39 Cortlandt Street, New York. Briefly, this bulletin explains such details as air supply, fixing the amount of water vapor,

heating, cooling, securing various humidities from one apparatus, air distributing systems based upon ordinary galvanized iron ducts, interior risers, hollow pilasters, central vertical flues, automatic dew point control, proportioning fresh and return air, etc. Further detailed description includes features of the Carrier humidifier—spray chamber, piping and nozzles, water pumping, heating and straining methods, air distributing baffles, fan, water eliminating baffles, fresh and return air dampers, compressed air system and safety valves for operating the dew point control, etc.

The Leeds & Northrup Company, Philadelphia, Pa., has issued Bulletin No. 875, describing the "potentiometer" system of pyrometry. The bulletin is nicely illustrated, showing installations of the pyrometer and working parts. A description is also given of the fundamental principle of the potentiometer, the development of the wiring scheme of the cold-end compensator and the automatic compensator. The method of determining transformation points is also described.

The Standard Car Construction Company, St. Louis, Mo., expects to have its new tank car plant at Sharon, Pa., completed and in operation about the first of September. The capacity will be fifteen cars per day, embodying the recent M. C. B. suggestions, i.e., double riveted tank, low running boards and jacking pads for raising underframe underload. The tanks are long, which lowers the center of gravity, and allows the use of 15-in. center still channels, giving the underframe great rigidity.

Crude Barytes Production.—The production of crude barytes in the United States in 1915 was 108,547 short tons, according to the Geological Survey, which is more than twice the 1914 production. There has been a large demand from the newly-established barium chemical industry.

Asbestos.—Asbestos was produced in this country in 1915 to the extent of 1731 short tons valued at $76,952, according to a Geological Survey report by J. S. Diller. This was a gain over 1914 of 484 tons. Most of our asbestos comes from Canada, and on March 25, 1916, an embargo was placed on shipments which shut off our supply from that quarter. This caused a great hardship, and the embargo has subsequently been modified to some extent to allow shipments to come into this country. Domestic sources are being investigated, and the encouraging outlook in Arizona, with the possible resumption of production in Vermont, together with an increased production from Georgia, may alleviate the situation considerably.

The Deschutes Hydro-Electric Process Company has been organized at Portland, Ore., with a capital of $350,000, to engage in the fixation of atmospheric nitrogen. The organizers are J. A. Jeffrey, C. D. Charles and E. Ferguson.

Nitre Cake.—As a substitute for sulphuric acid nitre cake is finding many uses. Nitre cake furnished by the E. I. du Pont de Nemours & Company, Wilmington, Del., has the following approximate composition:

	Per Cent
$NaH\ SO_4$	78
$Na_2\ SO_4$	18
Moisture	4
$FeSO_4$	Trace
Sulphuric acid equivalent, approximate	32
Sulphuric acid equivalent hot saturated solution, approximate	18

The product is variously known as sodium acid sulphate, sodium bisulphate, and acid crystals, and is readily soluble in hot water.

The Goldschmidt Thermit Company announces the removal of its general offices to the Equitable Building, 120 Broadway, New York.

Book Reviews

The Metallurgists' and Chemists' Handbook. Compiled by **Donald M. Liddell.** 4 x 7 in., 0.7 in. thick, 603 pages, price, $4. New York: McGraw-Hill Book Co.

The author, as managing editor of *The Engineering and Mining Journal,* had frequent occasion to consult tables of technical data, particularly in answering the thousand and one questions which are directed to such an encyclopedic and ubiquitous personage. Hence the resulting accumulation of useful tables and data, which now appears in pocket-bible form for the use of neophyte and adept. The various sections cover mathematics, price and production statistics, physical constants, chemical data, sampling, assaying, analysis, ore dressing, cyanidation, fuels and refractories, mechanical engineering, construction, general metallurgy, first aid.

The characteristic of the book is that it is not descriptive, but tabular and statistical. It is well selected and very carefully compiled; the author's intelligent discrimination is everywhere in evidence. Speaking as a metallurgist, the reviewer confesses that it is the first metallurgist's handbook which has suggested to him the thought, "Put me in your pocket!"

Elementary Practical Metallurgy. By **J. H. Stansbie.** 152 pages, 25 illus. Price $1.40 net. Philadelphia: P. Blakiston's Son & Co.

This interesting and useful book is certainly "elementary," but it is not what is commonly called "practical metallurgy." It would be properly described by the words, "Elementary Experiments for the Metallurgical Laboratory." It tells the student how to construct simple laboratory furnaces, make assays for gold and silver, test fuels, examine clays and slags, make simple mechanical tests, harden and temper steel, reduce a few oxides and sulphides to metal, work the thermit process, and make a number of bronzes, brass and white metal alloys. It is in these directions practically written, but is not very far advanced in scientific reasons or explanations. It might be Pepper's "Play Book of Metals" modernized into an elementary laboratory course.

A Text-Book of Practical Assaying. By **James Park.** 342 pages, 17 illus. Price $2.50. Philadelphia: J. B. Lippincott Company.

This is a revision and enlargement of the third New Zealand edition. "The field covered is the customary two years' course of assaying as given in mining and technical schools." It starts in with the most elementary steps, and leads up to the most complex problems of the assayer. But the author includes under the term "assaying" what would not be so considered in the United States, and here a word of explanation is necessary.

Professor Park defines assaying as "the valuation of ores, bullion and metallurgical products," and after saying that no hard and fast line can be drawn between assaying and quantitative chemical analysis, he repeats that "assaying is merely a specialized branch of chemistry dealing with metallurgical products." We are therefore prepared to find wet methods as well as fire assays given for the determination of the metals, such as lead, tin, antimony, bismuth, iron, manganese, zinc, chromium, and nickel. But what excuse is there for including under the author's own definition the analyses of rocks, soils, manures, waters, alcohol, sugar, milk, and petroleum?

The book is good, and a very useful one for a school course in assaying and quantitative analysis, but the author has handicapped it with the misnomer "assaying."

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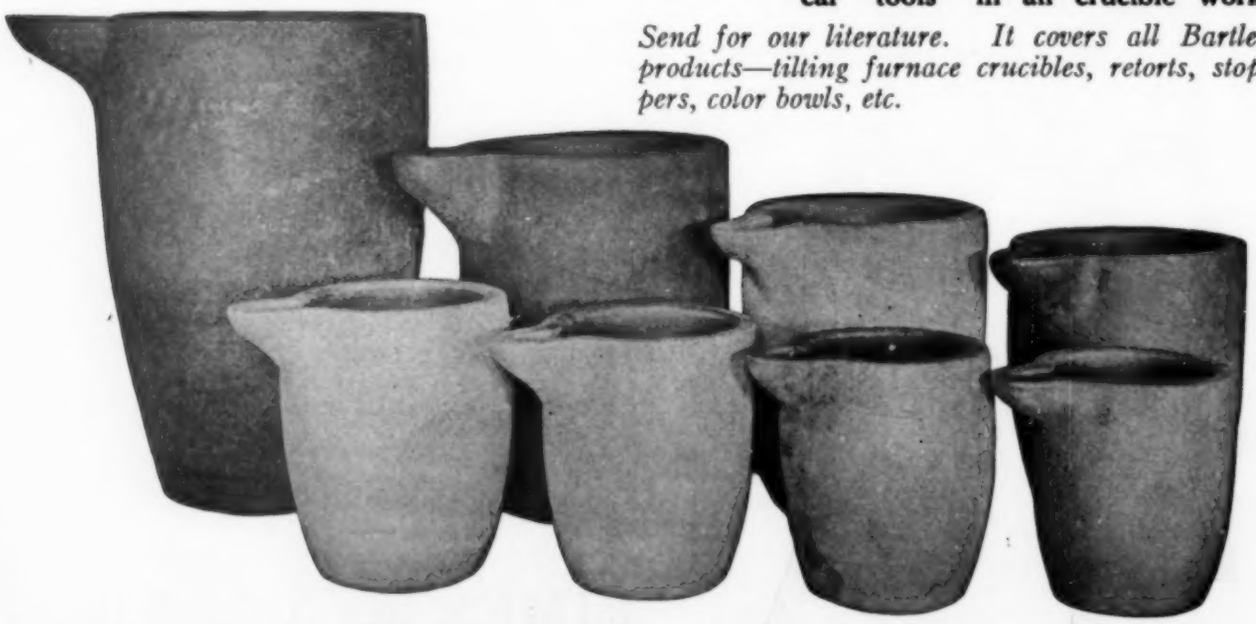

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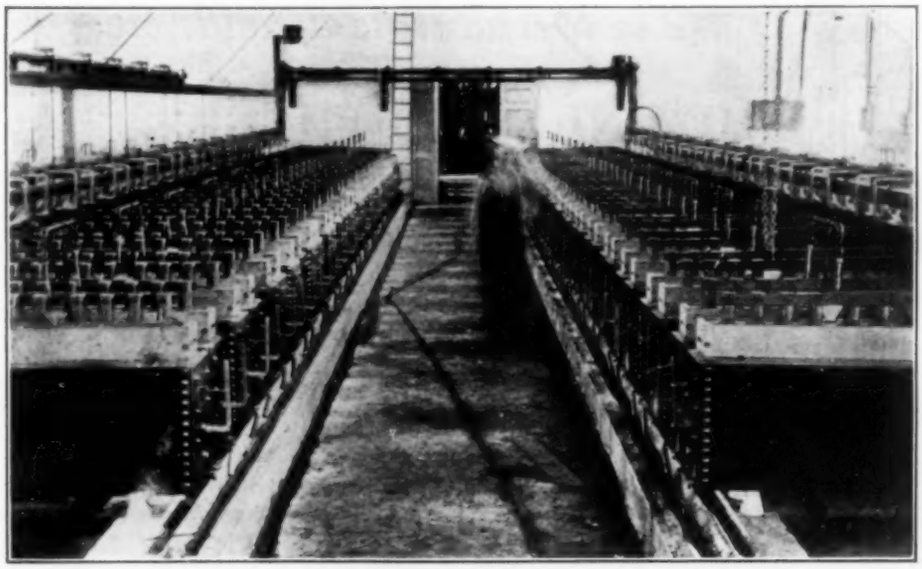

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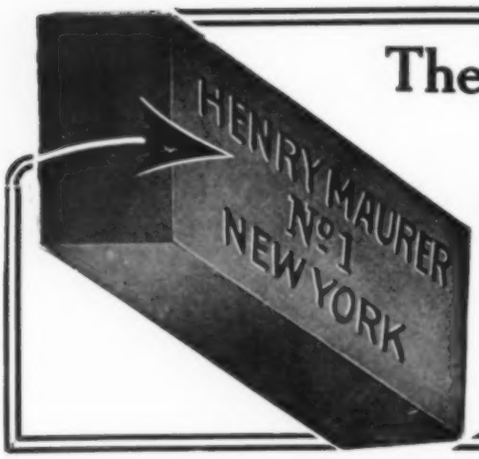

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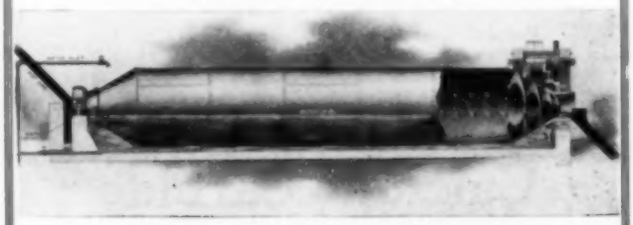

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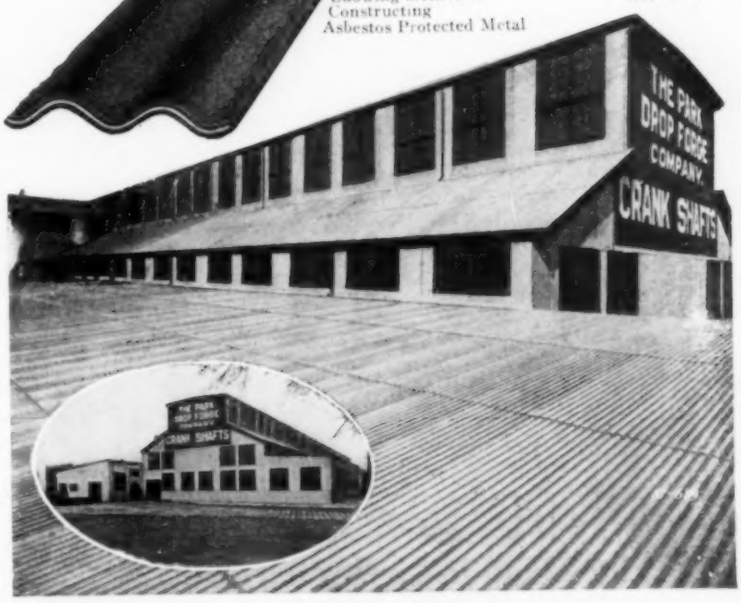

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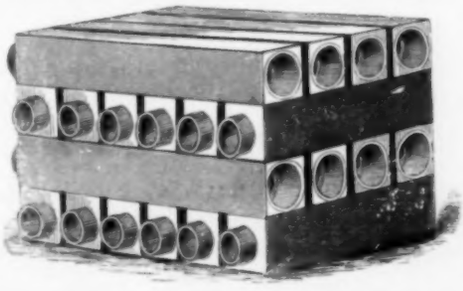

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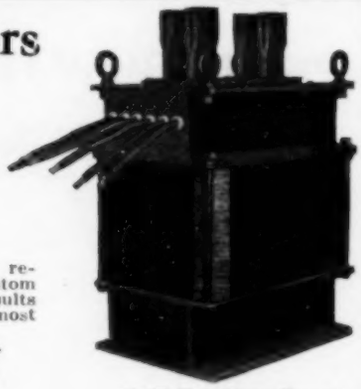

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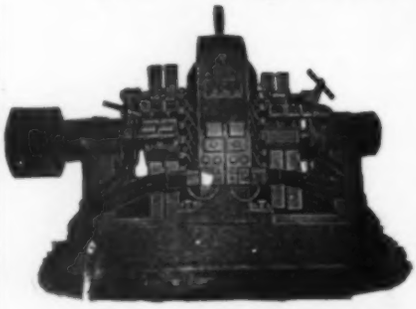
We pay the utmost attention to your requirements in the manufacture of "Custom Made" American Transformers. The results of our care plus your co-operation are most excellent. Send us data for estimate.

AMERICAN TRANSFORMER COMPANY

151 Miller Street, Newark, N. J.

150-K. V. A. Heavy Current Air-Cooled Transformer

Low Voltage Generators



Up to 10,000 amperes

Single, two and three voltages for School and Laboratory work. Deposition, Refining and Separation of metals.

CHAS. J. BOGUE ELECTRIC CO.

513-515 West 29th, New York

The Wiegand Chain Screen Door is a

SHEET OF CHAIN

before

Annealing, Glass or Chemical Furnace

Keeps heat in and cold out;
Permits clear view of interior;
No interference with handling contents;
Protects operator from heat and glare;
Saves Heat, Labor and Time.

E. J. CODD COMPANY

700 S. Caroline Street Baltimore, Md., U. S. A.

The Engineering Department of the

Bethlehem Steel Company

according to the Iron Age of May 18th said:

"Among the furnaces which were in operation in 1912, the

GIROD ELECTRIC FURNACE

as perfected by Paul Girod was considered the most satisfactory with regard to *economy and reliability.*"

The Girod furnace is in successful operation in units up to 25 tons per heat, and is particularly of value for the melting and refining of COLD charges of steel.

C. W. LEAVITT & COMPANY

Sole Agents

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HEAT TREATMENT

is the basis of many manufacturing operations and to make it better and cheaper required more than the mere burning of fuel. It requires furnaces properly designed to meet your particular working conditions.

Write for Booklet No. 21, "A Modern Heat Treatment Plant," for further particulars.

W. S. ROCKWELL COMPANY

FURNACE ENGINEERS AND CONTRACTORS

Hudson Terminal Bldg. 50 Church St., NEW YORK

Jantz & Leist Electric Co.

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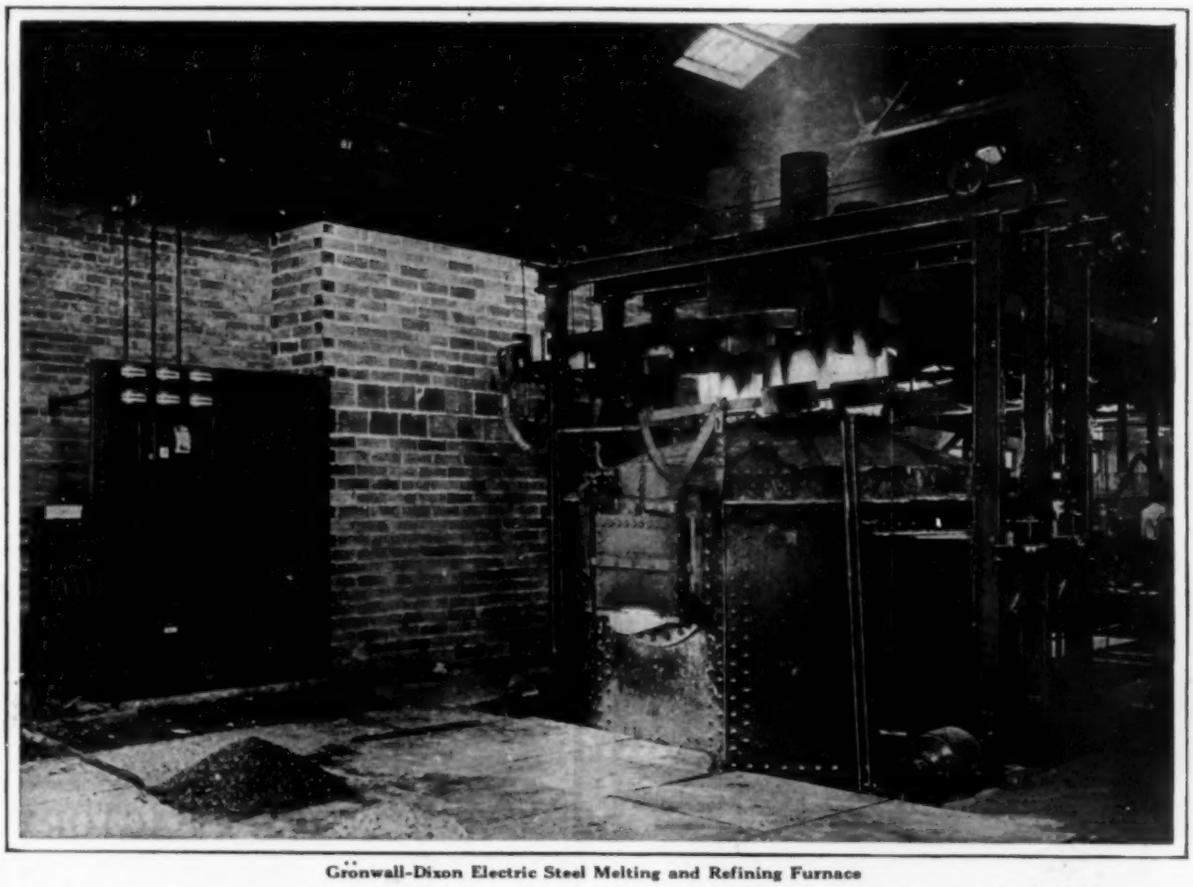
LOW VOLTAGE MOTOR GENERATORS

for general deposition of metals.

Liberal rating, excellent voltage regulation, durable, thoroughly Reliable Machines.

Tell us your problem.



Grönwall-Dixon Electric Steel Melting and Refining Furnace

John A. Crowley Company Sole Representatives and Sales Agents for United States
120-122 Liberty St., New York. Operating—Detroit, Mich.

RENNERFELT ELECTRIC ARC FURNACES

55 SOLD IN 3 YEARS. ***OPERATES ON A NEW PRINCIPLE.***

The arc is free burning and does not need the metal to complete the circuit. It is forced down on the bath in a large flame, instead of having one or more concentrated arcs between the tip of an electrode and the metal.

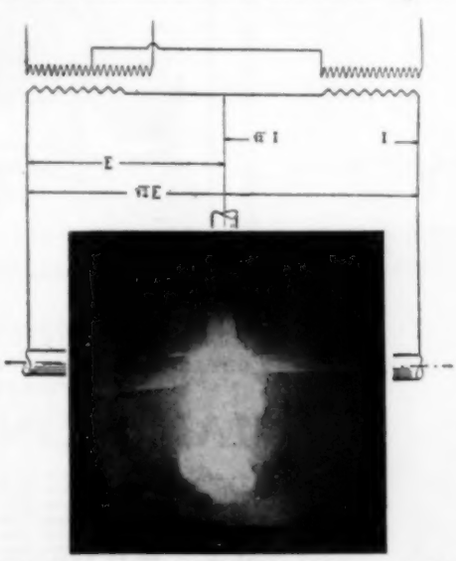
The arc being directionalized on the bath takes it away from the roof.

Roof has lasted 192 heats on steel and 375 melting iron with 9-inch brick.

Hence roof renewal infrequent.

Solid bottom like an open hearth.

From 1/3 ton, in 17 sizes up to 75 tons.



This shows the large flaming arc acting on the bath

Uses any kind of electric current.

Electrode consumption 2 1/2 to 5 lb. per ton of metal.

.9 power factor with 60 cycles.

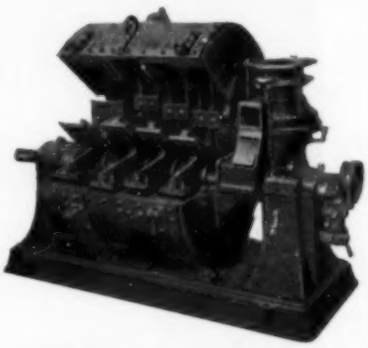
Making all different grades of steel today.

Also making Ferro-tungsten — melting Brass — Copper—Nickel and Ferro-manganese.

HAMILTON & HANSELL, 17 Battery Place, NEW YORK

Chicago Office, GLEN B. HASTINGS, 1511 Lytton Bldg.
Pacific Coast Agents: Woods, Huddart & Gunn, 444 Market St., San Francisco, Cal.
Address Foreign Inquiries to A. B. ELEKTRISKA UGNAR, Stockholm, Sweden

BURN PULVERIZED COAL BY THE AERO SYSTEM



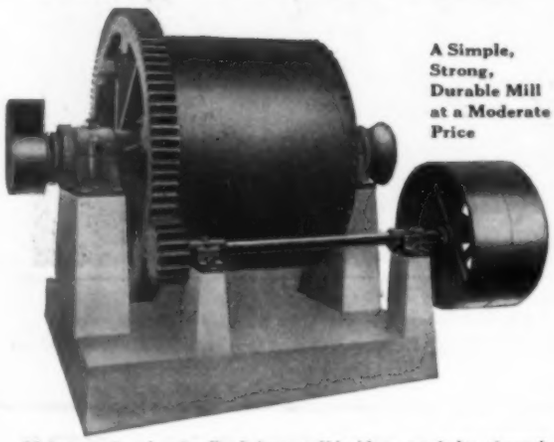
BECAUSE

1. It gets every available B.T.U. out of the coal.
2. Makes available slack coal and screenings at a fraction of the cost of mine run and lump coal and oil.
3. Eliminates the danger of fire or explosion from fuel in storage.
4. Both temperature and quality of flame accurately controllable at all times.
5. Construction prevents clogging by obstructions and guarantees continuous dependable action.
6. Perfect combustion is affected—No soot—no smoke, no free oxygen, no CO.

Shall We Send "Real Evidence"?

AERO PULVERIZER CO., Equitable Bldg., NEW YORK 5869

Standard Ball Mills



A Simple, Strong, Durable Mill at a Moderate Price

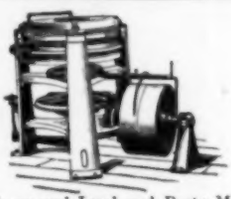
Lining made of spiegelized iron, self-locking, no bolts through shell. Scoop feed, trunnions, equipped with spiral feed and reverse spiral on discharge end.

The capacity and horsepower can be varied from above, depending on the steel ball charge, and is based on 1½ to 2-inch feed, and product 12-mesh and finer.

Capacity, Tons per Hour	Diameter Mill, Feet	Width Mill, Feet	Revolutions per Minute	Horsepower	Balls to Charge, Pounds
20	6	6	25	65	9,000
13	6	4	25	45	6,000
17	5	6	27	55	7,000
15	5	5	27	45	6,500
12	5	4	28	40	6,000
10	4	5	29	38	5,000
5	4	4	32	15	2,500
3	4	3	32	12	2,300

The Morse Bros. Machinery & Supply Company
1732 Wazee Street, Denver, Colorado

GRINDING MILLS



Improved Lead and Paste Mill

Disintegrators, Dryers
Chasers and Machines for

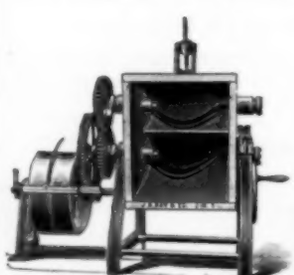
LABORATORY & FACTORY

Plans and Estimates for

SPECIAL MACHINERY
Promptly Furnished

THE J. H. DAY CO.

Office and Factory: Cincinnati, O.



Giant Kneading and Mixing Machine

Write for Catalog showing complete line of Mills and

MIXING MACHINES

Most Economical Grinding

FROM RESULTS OBTAINED BY OUR CUSTOMERS WE ESTIMATE THE CAPACITY, AS FOLLOWS, OF THE

MAXECON MILL

Limestone	4 tons	per hour to 95%	100 mesh
Florida Pebble	7 tons	per hour to 90%	60 mesh
Bauxite	4 tons	per hour to 95%	100 mesh
Hardest Ores	5 tons	per hour to 90%	50 mesh
Coal	4 tons	per hour to 95%	100 mesh
Silica	2 tons	per hour to 95%	200 mesh
Cement Clinker	10-12 bbls.	per hour to 98%	100 mesh

With Under 25 H. P. Minimum Wear and Repairs

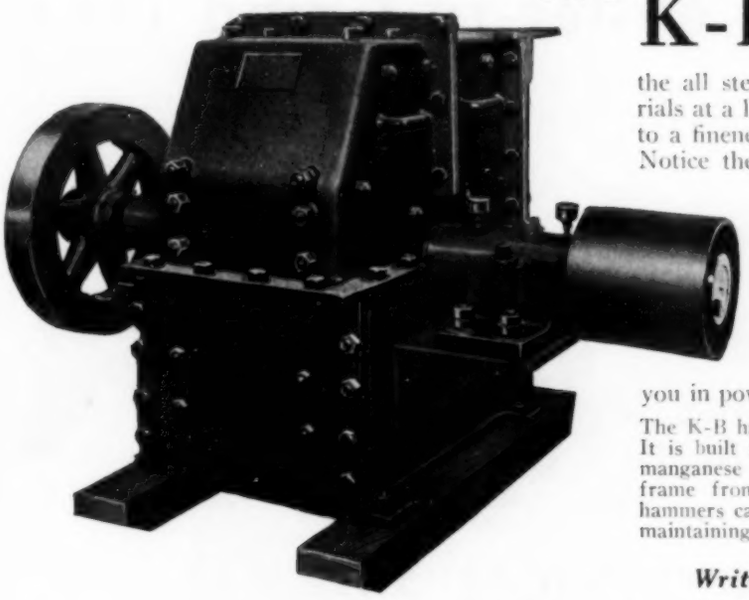
Used as a Standard Grinder by the United States Steel Corporation, Aluminum Company of America, Pennsylvania Salt Manufacturing Company, Virginia Carolina Chemical Company and practically universally in the chemical fertilizer factories of the United States and Europe. **Send for Bulletin 36.**

KENT MILL CO., NEW YORK, Borough of Brooklyn, 10 Rapelyea St.
BERLIN, Berlin-Hohenschoenhausen.
LONDON, 31 High Holborn.

From 3″ to Dust in One Operation

Use a

K-B Pulverizer



the all steel hammer-mill, to reduce your materials at a low cost from pieces of 3″ (and under) to a fineness of 10-20 mesh.

Notice the low power consumption—using only 10-15 HP., the No. 1 K-B will crush 4-7 tons per hour, and using only 20-25 HP. the No. 2 K-B will crush 10-15 tons per hour. Compare this low power consumption to that of other crushing machines, then figure for yourself the amount per year that the K-B will save for you in power costs alone!

The K-B has the strength to resist the hardest service. It is built entirely of steel, and, in addition, specially manganese hardened steel lining plates protect the frame from all wear. By an ingenious device, the hammers can be adjusted to compensate for wear, thus maintaining the uniform fineness of the product.

Write today for Bulletin M, to the

K-B PULVERIZER CO., INC. 86 Worth Street NEW YORK CITY

BUILT FOR SERVICE AND DURABILITY

There's an Abbé Machine to Solve Your Grinding Problem

The illustration below shows a Paul O. Abbé Jar Mill. The special method of fastening the jars into the mill eliminates the use of rubber bands. Jars cannot fall out.

Whatever your needs in the line of

Ball Mills, Jar Mills, Pebble Mills, Etc.

You will find satisfactory equipment described in the Paul O. Abbé Catalog. It lists **Crushers, Cutters, Sifters, Attrition Mills, Disintegrators, Cage Mills, Respirators, Dufour Bolting Cloth, Etc.**

Write now for quotations on anything you need in such equipment.

Single Assay Mill with Specimen Jar

PAUL O. ABBÉ

Crushing, Cutting, Grinding, Mixing, Pulverizing and Sifting Machinery

Room 920, Johnston Bldg., New York

Do You Run *Your* Pebble Mill For Hours in Order to Grind Fine

and then while discharging allow the pebbles to break and put **coarse foreign matter** in **your finely ground** material?

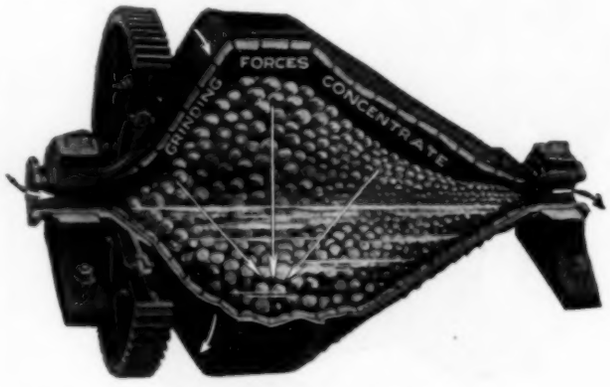
Ever Thought

of how wasteful this method is, and how easily you can spoil expensive material?

If you ground **continuously** this could not happen.

The 3 HP. HARDINGE PEBBLE MILL or the 6 HP. HARDINGE BALL MILL grinds continuously.

Write for details



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120 BROADWAY, NEW YORK

Cable Address: HALHARDING, NEW YORK

V. A. STOUT
California Sales Agent
Balboa Building, San Francisco, Cal.

MEAD MILLS

Mead Mills are of the high speed disc type, reducing the material by impact. In design and construction they represent the highest achievement in grinding machinery. The beaters are made of hand forged tool steel, constructed and attached to give the greatest cutting power. These mills can be regulated to give the desired degree of fineness.

Send for catalogue and complete information.

MEAD & COMPANY
Detroit, Michigan, U. S. A.

The following are a few of the prominent manufacturers using Mead Mills:

American Car & Fdry. Co.
American Glue Co.
American Chicle Co.
American Graphophone Co.
American Crayon Co.
American Agric'l Chem. Co.
Clinchfield Products Corp.
Cudahy Packing Co.
Durex Chemical Co.
Dunlop T. & Rub. Goods Co.
Eastern Tanners Glue Co.
Goodyear Tire and Rub. Co.
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Mallinckrodt Chemical Wks.
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Pathe Freres Phonograph Co.
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For accurate proportioning in your mixing and compounding operations, install the

POIDOMETER

(the better automatic weighing machine)
Our new illustrated catalogue will be ready soon. Write now for your copy.

The Schaffer Engineering & Equipment Co.
Tiffin, Ohio, U. S. A.

The Morgan Producer Gas Machine

is the highest class gas producer built in the U. S. and is advertised in the 1st of the month issues of this journal.

Morgan Construction Co.
Worcester, Mass.

SMITH SECTIONAL GAS PRODUCERS

Clean, cold producer gas in unlimited quantities

High in quality and uniform in heating value.

The Smith System produces a tar-free gas—a clean fuel for particular manufacturing processes.

THE SMITH GAS POWER CO., Lexington, Ohio

The Wise Agitating Sulphur Burner

(Patented United States and Canada)

Efficient Simple Durable
Prompt Deliveries

Carthage Machine Co. **Carthage, N. Y.**
(Sole licensed manufacturers)

Six Points of ABBÉ Superiority

No. 6—Uniform Results

Combination Laboratory Mill

What are uniform results? Simply getting what you **want**—getting it **continuously**—and in the quantity you **want** it. In other words, satisfactory output, according to the kind of service the machine is **built for**—and this is a big characteristic of Abbé Equipment. **We know how** to build machinery that is, and remains, unexcelled in its particular field of service. In brief ABBÉ results are UNIFORM results—uniformly **satisfactory.**

We make Laboratory Mills, Jar Mills, Pebble Mills, Ball Mills, Tube Mills, "Max" Mills, Vacuum Pumps, Pressure Blowers, Rotary Cutters, Disintegrators.

Use Our Testing Laboratory

We make no charge for grinding, crushing, cutting or mixing samples and submitting full reports on suitable machines. Get in touch with us. Take advantage of our 39 years' experience.

Improved "Max" Mill (Patented) for Grinding Nitre Cake, Arsenate of Lead, Salts, Lime, Sugar, etc.

ABBÉ ENGINEERING CO.
218-220 Broadway, New York

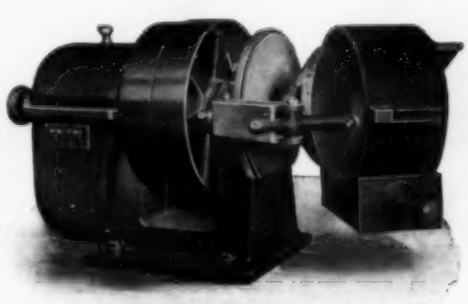
Jammed full of merit:

THE McCOOL PULVERIZER

For rapid grinding of ore samples and preparation of control pulps in sampling departments

Recognized by many large and important users as the best machine for the work that has yet been developed.

Two discs, one remaining stationary, do the work, and these discs always remain smooth and serviceable. You can grind as fine as you choose, and regulate the degree of fineness while machine is running. Combines large capacity and high speed with simplicity and durability.



For Chemicals, Laboratory Apparatus, Instruments, etc., "Massco" Clay Goods, Crucibles, Scorifiers and Muffles, all of high quality, write to us.

We are headquarters for laboratory supplies

The advantages of centralized buying were seldom more emphasized than in the opportunity we offer of obtaining a large line of materials and supplies from one reliable source.

Mine & Smelter Supply Co.

Denver **Salt Lake City** **El Paso**

New York Office, 42 Broadway

Broughton Mixers

For THOROUGH incorporation of various materials, at minimum cost.

Thorough because of the principle of mixing. The work is done by a double set of paddles placed on their shafts at opposite tangents and revolving in opposite directions. Materials which bunch up, clog or refuse to incorporate in other mixers are perfectly combined in the Broughton.

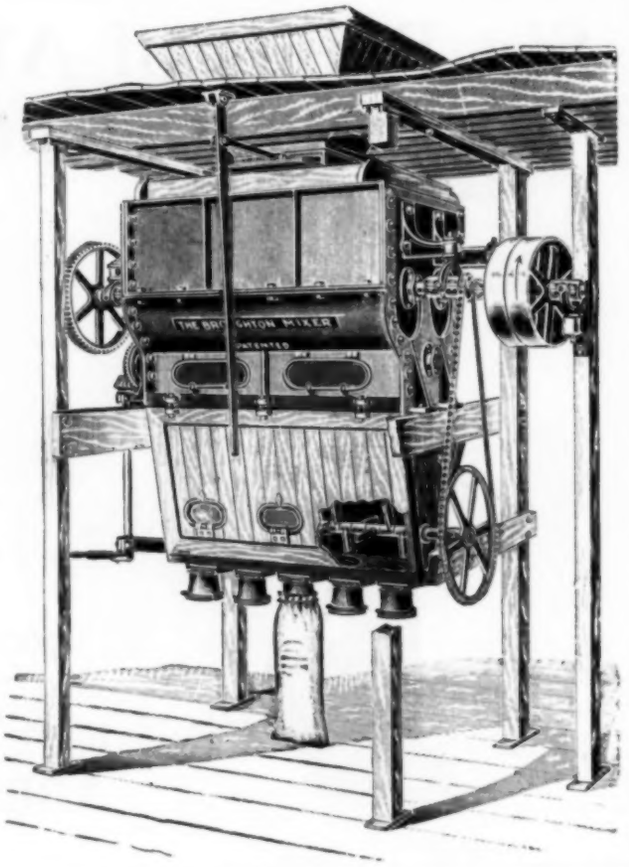
Economical because of the small power required, the constant supply of mixed materials always ready for the bagger, and the durability and long life of the machine.

While one charge is being bagged, another is being mixed and a third is being put into the receiving hopper above the mixer.

Many other points of superiority.

Mail a post card for "Blue Book on Better Mixing".

W. D. Dunning, Syracuse, N. Y.



Ore Dryers

RUGGLES-COLES DRYERS

DIRECT INDIRECT STEAM

"BUILT TO DRY AT THE LOWEST ULTIMATE COST"

Of over 500 in operation, 123 have been sold on repeat orders.

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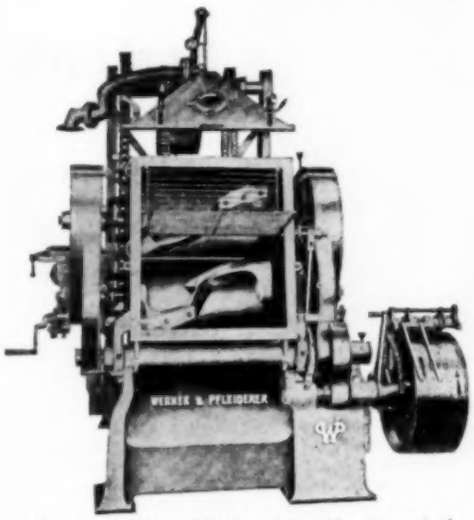
Electro Metals, Ltd., 9½ Union Court, Old Broad St., London, Eng.

We Aim to be of Service



Vacuum Kneader—Interior view with cover raised

wherever masticating, mixing, kneading, incorporating and pulping is required.

By our wide experience extending over many years in the building of such machines we are able to handle advantageously practically all kinds of such propositions.

Inquire concerning our

Mixing Machinery,
Vacuum Kneaders,
Automatic Weighing Scales,
Rubber Machinery,
Marconi Presses and Rapid Dissolvers.

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Dorr Agitators Are Power Savers

The Dorr Agitator (Patented)

A plant operating a Dorr Agitator in a tank 30 x 10′ used less than 0.2 of one H. P. with 20 cubic feet of low pressure air per minute. A paddle arm Agitator of like dimensions and operating at the same plant required 8 H. P. and 30 cubic feet of air.

The Dorr Agitator consists of a rotating mechanism with central air lift. It may be installed in a flat or conical bottom tank and may be operated continuously or intermittently.

Dorr Agitators have demonstrated their adaptability to the Chemical Industry and are meeting with marked success. Constructed of non-acid or acid-resisting material.

Write us for agitator data.

THE DORR COMPANY

ENGINEERS

Successors to the Dorr Cyande Machinery Company

NEW YORK
17 Battery Place

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1009 17th Street

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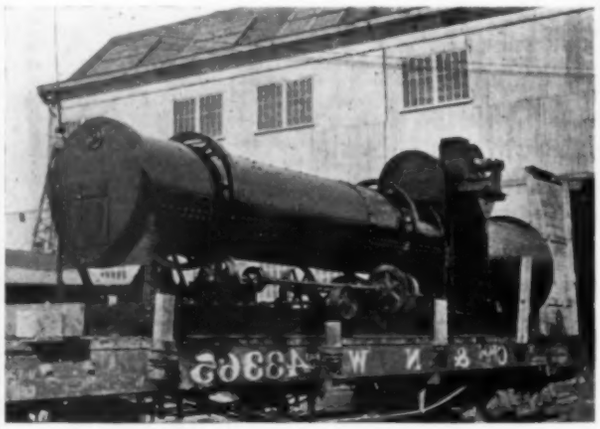
The Manitowoc Semi-Portable Dryer

is shown below. The same good material and workmanship goes into its construction as into the larger sizes—and it is designed to give equally good service.



MANITOWOC dryers will save money you have already earned and help you to earn more. They are designed to deliver the maximum amount of uniformly dried material at minimum cost—and without injury. Many new installations and repeat orders prove that this is being done.

One User Writes

"It will, no doubt, interest you to know that this Manitowoc dryer is giving us splendid satisfaction. We hope the time will come when we will find it necessary to put in another new dryer." This is indelible proof—and it came unsolicited.

WE CAN DRY:

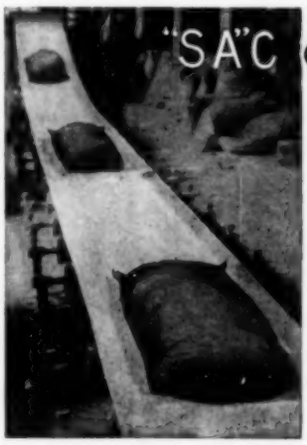
Beet Pulp	Fullers Earth	Manure
Blood	Garbage	Ore (Various)
Bones	Graphite	Phosphate
Chemicals	Guano	Plaster
Clay	Gypsum	Salt
Clinker	Infusorial Earth	Sand
Coal	Kaolin	Starch
Fish Scrap	Lime	Tankage
		Wood Chips

Write for circular—just issued

Manitowoc Engineering Works

Designers and Builders of Dryers, Digesters, Cookers, Chemical Tanks, Welded Vessels and heavy plate fabrication.

Manitowoc, Wis.



"S-A" Conveying Systems

help to make you independent of unskilled labor—

In hundreds of plants and factories "S-A" Conveyors are unloading and storing the raw materials, delivering them to the various processes of manufacture and delivering the finished product to storage or to the shipping platform. "S-A" Conveyors are designed by experienced engineers to meet individual conditions in any factory and to handle all bulk or package products.

Correspondence or consultation is invited with nearest office.

Stephens-Adamson Mfg. Co.

Aurora, Illinois

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Why Make Patterns?

Whether you want *one gear* or *one hundred*, why go to the *expense* of *making patterns?* We can furnish you *machine molded gears* and *save you pattern expense.*

By the Machine Molding Process all the teeth in a gear are molded from a single tooth pattern, the spacing being done by accurate machinery.

A machine molded gear is, therefore, more accurate, better balanced and as nearly perfect as a cast tooth gear can be made.

SPUR, BEVEL, MITER and WORM GEARS machine molded—1" to 6" pitch.

MORTISE WHEELS with dressed teeth and cogs.

We are equipped to furnish gears with *Machine Cut Teeth.*

Our No. 38 catalog lists the gear you want. Over 100 pages of gear lists and useful information. Have you a copy?

H. W. CALDWELL & SON CO.

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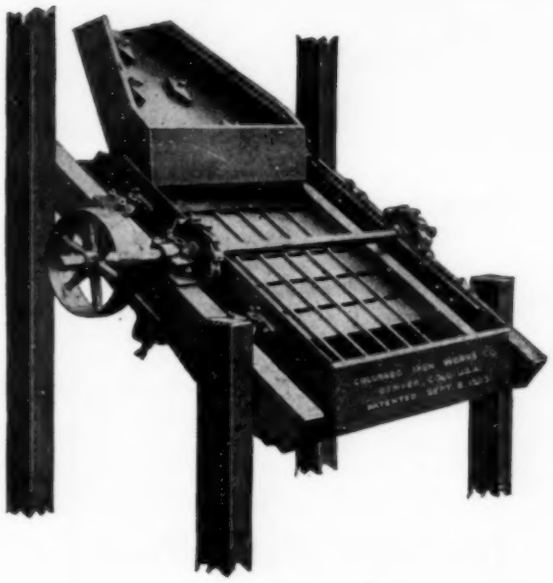
1860

COLORADO IRON WORKS COMPANY

ORE SMELTING EQUIPMENTS

ORE MILLING MACHINERY

1916



The Impact Screen

It has been in just those mills where the full advantage of efficient sizing is most keenly appreciated, and where the greatest capacity and lowest cost of maintenance are demanded, that the Impact Screen has most signally demonstrated its superiority over all other Screening devices.

It has most emphatically "made good."

We are exclusive manufacturers of the

Callow Flotation Apparatus

in and for the state of Colorado.

Colorado Iron Works Co.

Main Office, 33rd & Wynkoop **Downtown Office, 206 Ideal Bldg.**

Denver, Colo., U. S. A.

The Minerals Separation Flotation Processes

Invented, Perfected and Owned by

MINERALS SEPARATION, Ltd.

***of* 62 London Wall, London, England,**

and Its Affiliated Companies.

The Processes are protected in the United States of America by over forty patents and applications for patents, which include practically everything essential or of value in the use of the Process and Art of Air Froth Flotation of mineral values, *irrespective of whatever mechanical apparatus may be employed.*

The Processes are now in almost universal operation, yielding phenomenal recoveries and record breaking profits wherever properly installed, as at Anaconda, Braden, Britannia, Inspiration, Timber Butte, and numbers of other important Copper, Zinc, Lead, Silver and Gold Mining Plants throughout the World.

The Plant is simple, inexpensive and "Fool Proof" and occupies very small space for its large tonnage capacity.

The Patent Rights for the United States of America, Canada, and Mexico are controlled by

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INFRINGERS WILL BE PROSECUTED

"This concrete is sure to be Waterproof"

I JUST measure out two pounds of this dry powder to each bag of Portland Cement and it makes concrete that is waterproof.

R.I.W. TOXEMENT
REMEMBER IT'S WATERPROOF
REG. U.S. PAT. OFF. PATENTED

is an integral waterproofing compound for concrete, stucco, Portland cement mortar, etc.

It comes in bags like cement and is added in small quantities at the mixer.

Does not hasten or retard the setting, but lubricates and insures concrete that is watertight.

Used in the Woolworth Building, The Yale Bowl, Cooper Institute Annex, Lehigh Valley Grain Elevator, Dry Dock Brooklyn Navy Yard, etc. **Write Dept. T for the "Toxement" Booklet.**

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is vital to the success of an electrochemical works. Such operation is dependent entirely on the reliability of the water wheels installed. Pelton-Francis turbines and Pelton-Doble tangential wheels are built rugged and simple, to assure uninterrupted service. Instances where our wheels have operated without a single shut down for periods in excess of one year, are so numerous that we have ceased to think of these as records. Our catalogs explain fully the reason why.

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AUTOMATIC CRUSHING
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SAMPLING MACHINE
COMBINES THREE
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THREE SETS OF ROLLS
IN
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It prepares your sample for the laboratory, eliminating the personal equation from all operations.

IT COMBINES

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See the result of a U. S. Government Bending Test—Machined Monel Metal bar, showing toughness and ductility without fracture. Bar had been previously machined to bring out any slight defects that might develop on the surface due to stretching of remotest fibres.

Monel Metal

Monel Metal is not only tough by physical tests but tough and wear-resisting under exposure to acid fumes, gases, atmospheric conditions and other corroding influences. Monel metal endures where ordinary metals give out. Write for particulars regarding your problems.

Ask to have the "Supplee-Biddle Bulletin" sent you every month.

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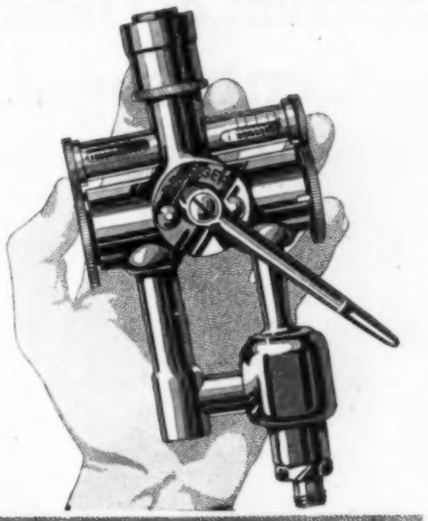

This valve makes possible the first hand-operated resuscitation machine employing the only principle recognized as correct by physiologists — that of *accurately measured pressures.* It's an *exclusive* feature of the

new type B Pulmotor

Up to the present, all hand-operated resuscitation machines have depended upon the individual effort and intelligence of the man at the pump—there being no controlling device interposed between the pump and the patient's lungs. Consequently the pressures varied according to the amount of pumping done, often to the serious detriment of the patient.

The *Pulmotor Pressure Control Valve* corrects this. Interposed between the pump and the patient's lungs, it insures uniform, *measured pressures*, adapted to the specific needs of each case. The control is centered in the operator. *Indicator Gauges* show him precisely what pressures are being exerted, both of inhalation and exhalation.

Type "B" Pulmotor overcomes every inherent defect of the *pump-controlled* machine. It can be successfully used by even an unskilled operator. It weighs only 12 lbs. with carrying case and is instantly ready to be taken anywhere in emergency. Price complete $115.

Order now to insure prompt delivery.

There is but one genuine PULMOTOR, the genuine always bears the name DRAEGER.

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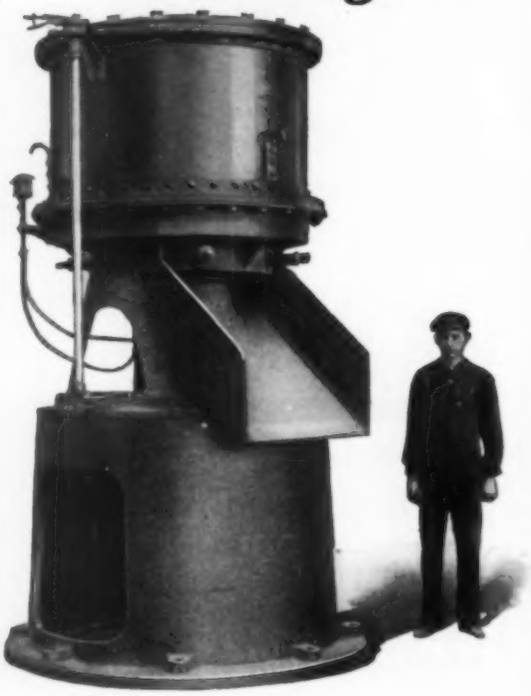
AGENTS for Wolf Safety Lamp Co. of America

Schaum & Uhlinger Centrifugals



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THE efficiency of this type "SI" machine is gained through the highest order of materials and workmanship, and a practical design that makes for ease in operation and maximum of output.

For the drying of heavy chemicals it has particular advantages:

Acid resisting metals are used where advisable.

It discharges from the bottom.

It operates with either motor or belt drive. Bearings are ample, with lubrication properly provided for.

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We will gladly co-operate with you in determining the practicability and cost of drying your materials.

Describe the special conditions in your plant, and we will send you the definite information you need to consider S. & U. machines.

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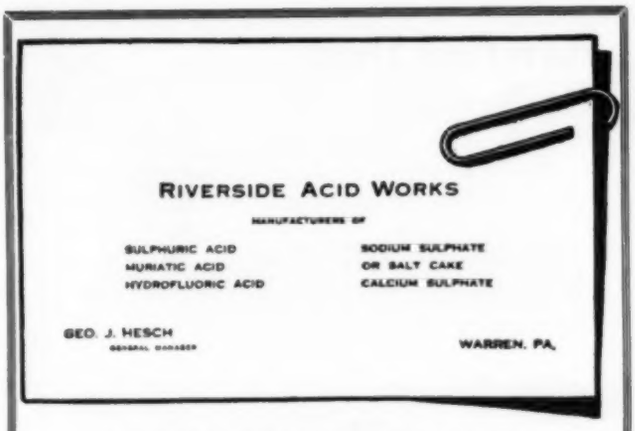

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Right now our production is spoken for and we can't supply you.

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60° 66° 97%

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Bulletin No. 100

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We have therefore explained air conditioning in general in this bulletin and also such details in particular as proper air supply; fixing the amount of water vapor; heating; cooling; securing various humidities from one apparatus; air distributing systems based upon ordinary galvanized iron ducts, interior risers, hollow pilasters, central vertical flues, etc.; automatic dew point control; proportioning fresh and return air, etc.

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Compressors and Vacuum Pumps
4 to 400 cu. ft. Capacity
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Blowers, Gas Pumps, Water, Vacuum and Liquor Pumps.
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Standard Over Driven Centrifugals easily handle large, unbalanced loads by gravity—without springs, rubber cushions or other makeshift devices.

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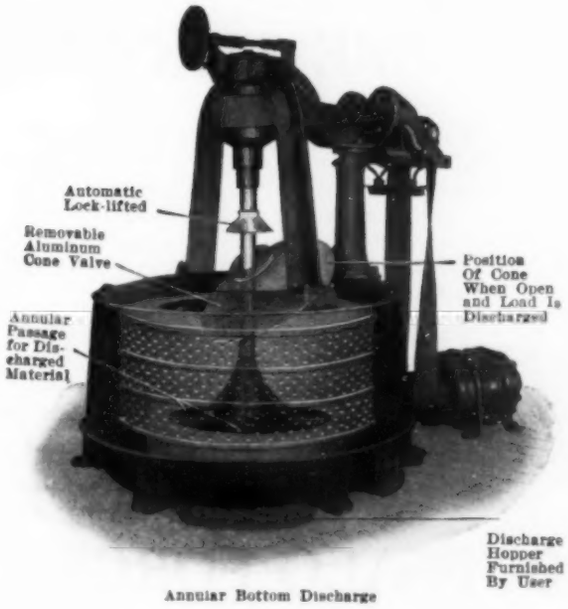
Equipment and apparatus that increases both the volume and quality of your output is a wise investment. For continuous and exacting service install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The industrial perfection which depends upon ideal atmospheric conditions in your plant can be obtained by means of Webster Service and Webster Air-Conditioning Apparatus.

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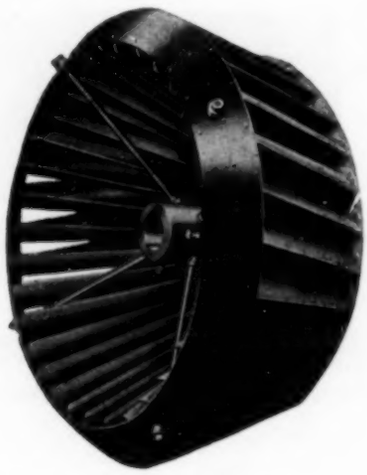
BUFFALO

Niagara Conoidal Fans ARE STRONGEST



One of the largest American concerns has occasion to use fans for service where sudden starting and stopping is necessary. A testing machine was used to approximate actual working conditions, by bringing the fan wheels from rest to 1500 r.p.m. and stopping in one second.

Fans of a well-known make—multiblade type—after several improvements and changes in design made as their best tests 2580 and 1488 cycles of starting and stopping before they went to pieces.

A Conoidal Wheel, the only one offered, and without the advantage of previous test, had made 37,333 cycles when the shaft of the testing machine broke, leaving the fan apparently in good condition to go on indefinitely as reported by the buyers' Engineers.

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Evaporators, Dryers, Chemical Apparatus and Ice Machines

Following is a partial list of apparatus on hand and for sale. LET US KNOW your requirements. Full list of slightly used machinery and apparatus sent on application.

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2—Single effect 300 gallons per hour
2—Double effect 300 gallons per hour
1—Triple effect 300 gallons per hour
7—Single effect 1000 gallons per hour
1—Quadruple effect 1000 gallons per hour
6—Single effect 1000 gallons per hour
4—Single effect 600 gallons per hour
2—Double effect 600 gallons per hour

Evaporators
Copper Heating Surface

1—Single effect 1000 gallons per hour
1—Double effect 1000 gallons per hour
1—Single effect 500 gallons per hour

Dryers

3—Double roll drum dryers
1—Single roll drum dryer
2—Vacuum dryers
1—Rotary vacuum dryer
1—Rotary steam dryer

Chemical Apparatus

Stills
Kettles
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50-ton consolidated machine; two 12 x 30 vertical single acting compressors and one 18 x 36 vertical steam engine.
50-ton De La Vergne vertical oil system machine; two 9¾ x 24 double acting compressors and 18 x 24 Corliss steam engine, 50 RPM, 50 tons at 27 lbs. back pressure, 38 tons at 15 lbs. back pressure.
1—11¼ x 22 vertical De La Vergne Machine, Ser. 904.
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Both dry system.
De La Vergne Refrigerating machine, 6 x 9 belt drive and equipments. This machine has a capacity of 6 tons refrigerating.
2—50-ton De La Vergne ice machines
1—12 x 24 S. A. vertical.
1—13 x 22 Horizontal, D. A.
20, 25 or 30-ton machine.
50-ton compressor, De La Vergne. 20 x 20 hor. st. cyl. Corliss valve gear, and two 10¾ x 20 vertical D. A. compressor cylinder.
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Also full line of vacuum pumps and condensers

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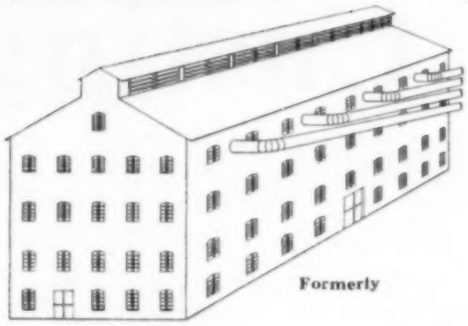
Fume Collection **Pigment Recovery**



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Air is exhausted steadily, without shock or jar. By carefully machining the impellers all over with special tools, they are able to maintain small, uniform clearances throughout their entire revolution, without touching the case or each other at any point.

The shaft bearing being the largest friction directly traceable to the pumping medium, 24-hour service can be *constantly* maintained without heating or causing the slightest trouble.

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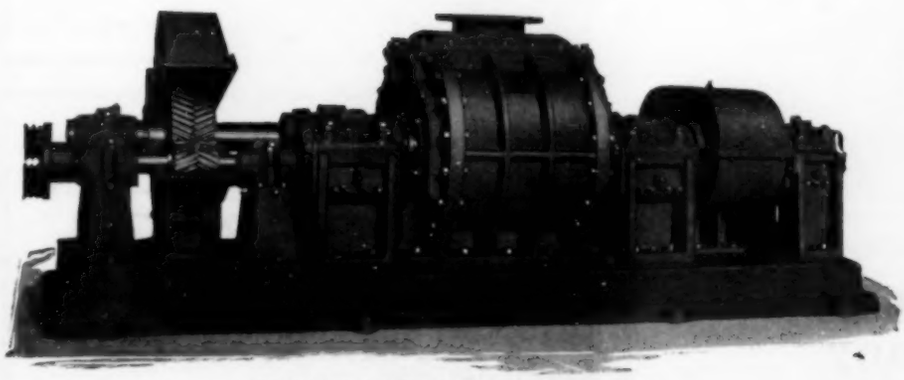

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Blowers for Flotation

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Perhaps you are developing a new process which calls for the use of a material of unusual properties. You find that you need something that is resistant to acids and must possess at the same time good electrical conductivity. Or, perhaps it is refractoriness with low thermal conductivity that you are after. We say—investigate carbon!

Again, you find that in addition to these properties you require this material in special shapes—large or small sections. It must possess good mechanical strength. And, most important of all it must be inexpensive. We repeat—investigate carbon!

Carbon, because of its remarkable characteristics, is having a wider and wider use in the chemical and metallurgical industry.

As manufacturers of carbon products for over twenty-seven years we are in a position to furnish carbon products of every description in a most satisfactory manner.

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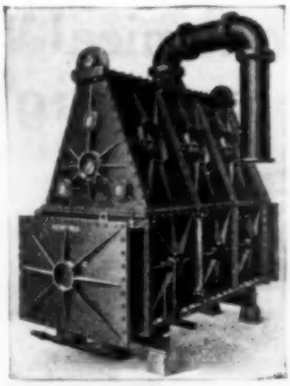

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For Chemical, Metallurgical and Industrial Plants

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LET OUR ENGINEERS
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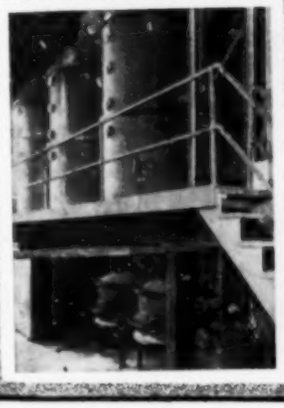

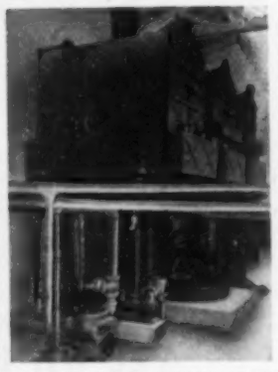

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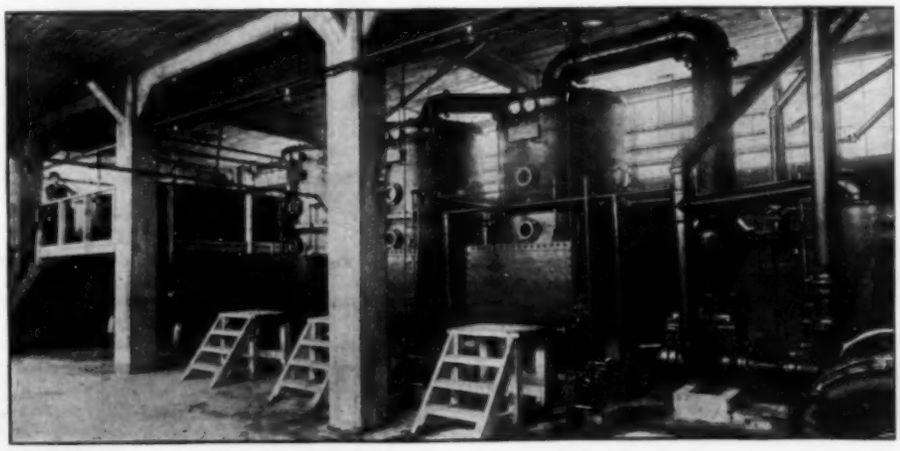

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The only apparatus that provides insurance against the results of carelessness and ignorance

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Finishing Touches

After the **Sperry Filter** plate has been carefully turned on an accurate machine tool, it is not yet complete.

Each plate is separately gone over by two workmen, who scrape off all projections and file all rough edges.

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Let us figure on your filtration problems.

D. R. SPERRY & CO., Engineers and Manufacturers
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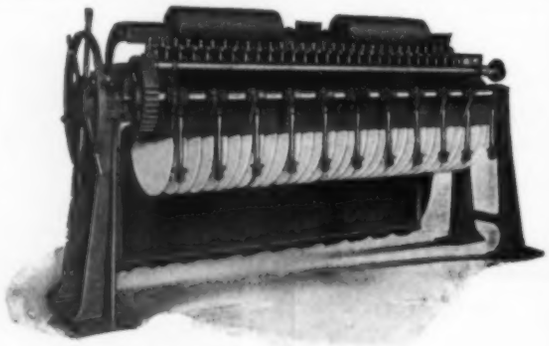

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Sweetland Self-Dumping Filter

This filter saves labor, is economical in filter cloth, has interchangeable filter leaves and requires a minimum floor space.

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FILTER PRESSES

We make all sizes from 18 inches to 40 inches square. For acids and chemicals where liquid should not come in contact with metal. Write for information and prices.

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are built for all capacities. Service and accessibility are the keynote of our construction.

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Engineers—Land and Marine—Manufacturers
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We Can Save You Money on Filter Cloth—

Whatever your filtering problems, we can supply you just the right quality of cloth to do the work most efficiently.

We make filter cloths from 1/64 to ½ inch in thickness, and in all grades of openness.

Write today for samples of grade you desire.

F. C. HUYCK & SONS, Kenwood Mills, ALBANY, N. Y.

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"Kemetaline" Valves, with their heavy, non-brittle bodies, are **strong where the strain comes.**

Our lined pipes and fittings are preferred and specified by some of the largest acid chemical and oil manufacturers in the United States.

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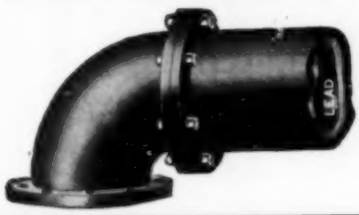

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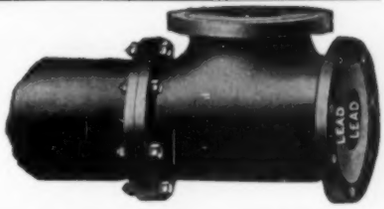

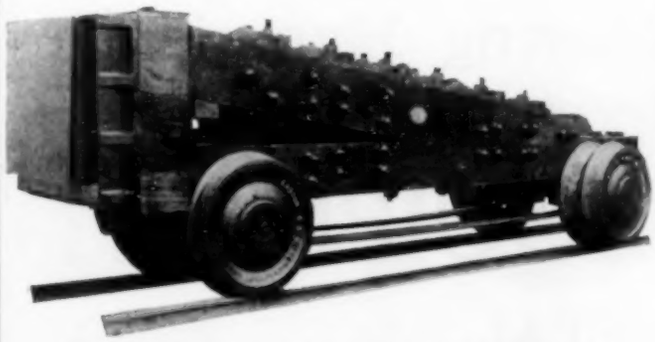

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A "Barney" Car

Another Special Easton Type Another Car Problem Solved

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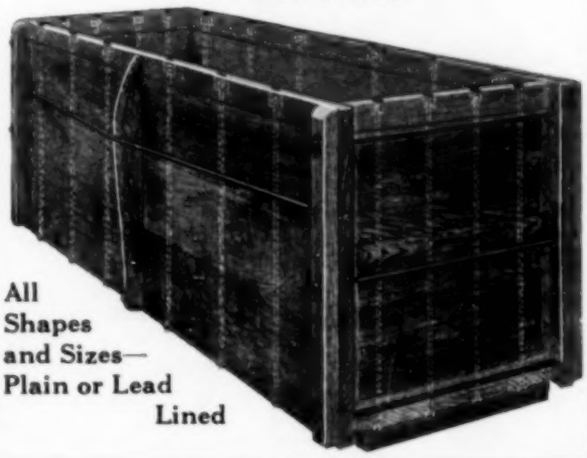

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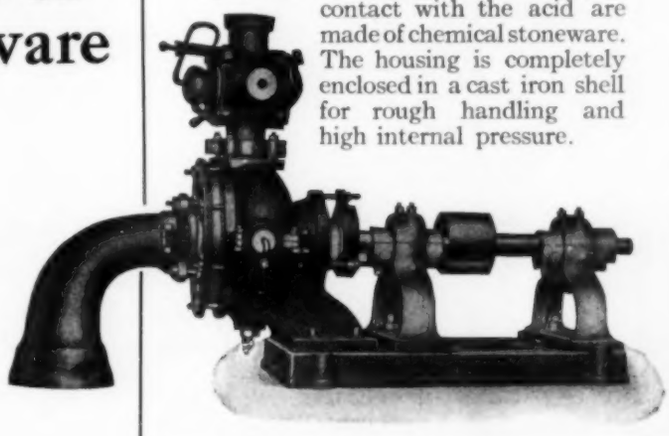

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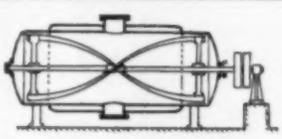

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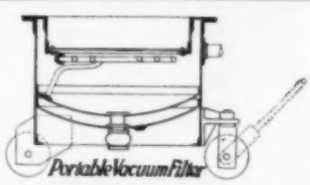

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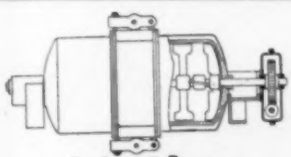

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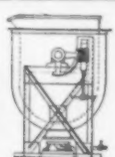

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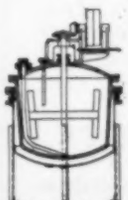

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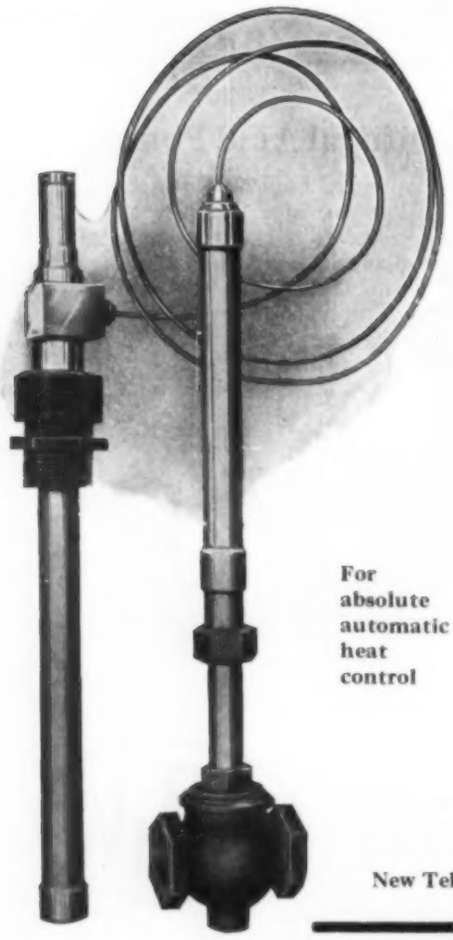

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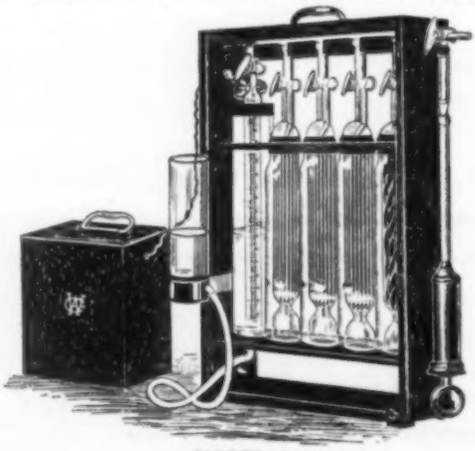

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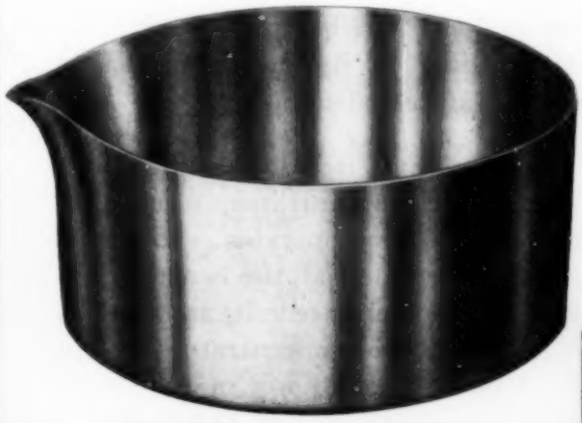

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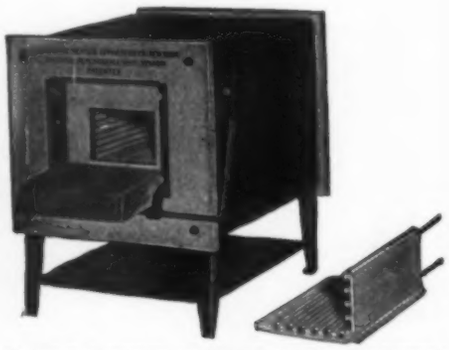

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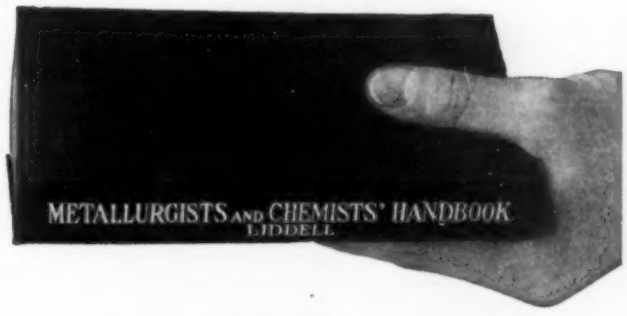

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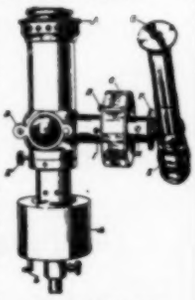

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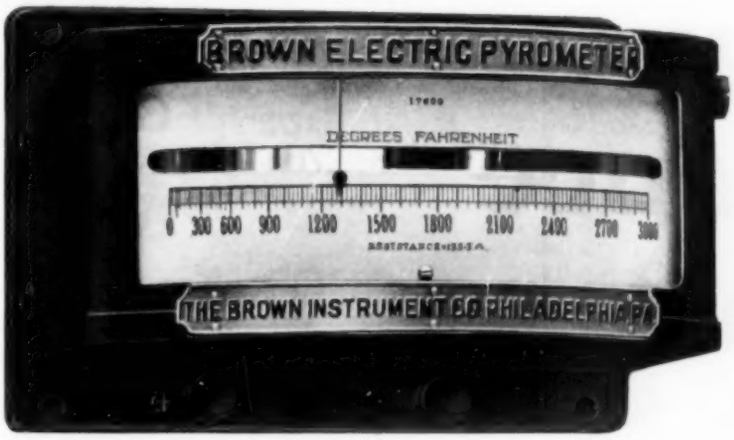
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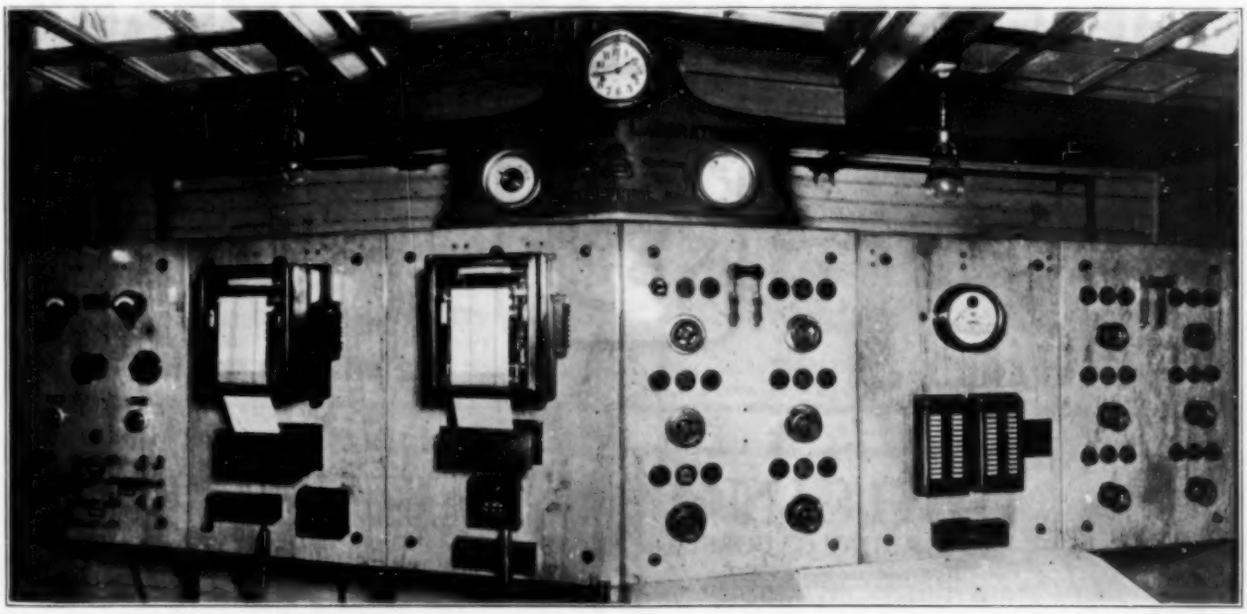

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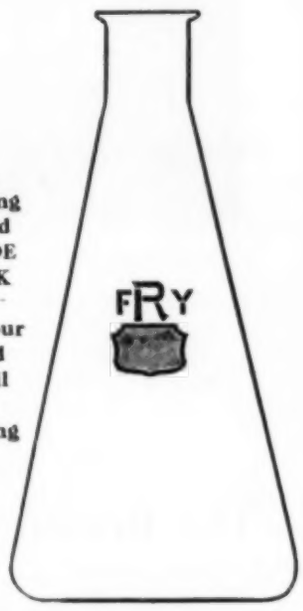

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One Chemical Concern has recently given us a REPEAT ORDER for

FORTY-FOUR

THWING

HIGH RESISTANCE MULTIPLE RECORD

PYROMETERS

This is a Strong Indorsement

Thwing Instrument Company
443 N. Fifth Street, Philadelphia

The April Issue Contains:

UNIVERSAL ELECTRICITY SUPPLY
By SAMUEL INSULL, President, Commonwealth Edison Company, Chicago.

AFTER THE WAR
By ALBA B. JOHNSON, President, Baldwin Locomotive Works, Philadelphia.

THE NECESSITY FOR A NATIONAL DEPARTMENT OF PUBLIC WORKS
By ISHAM RANDOLPH, Consulting Engineer, Chicago.

THE EXTENT TO WHICH SEWAGE CAN BE PURIFIED BY PRACTICAL METHODS NOW IN USE
By HARRISON P. EDDY, Metcalf & Eddy, Consulting Engineers, Boston.

PROCEEDINGS

The Engineers' Society of Western Pennsylvania
50 cents per copy $5.00 per year.
ELMER K. HILES, Secretary, 2511 Oliver Bldg., Pittsburgh.

Standard Chemical Company
Miners of Uranium and Vanadium Ores
General Offices, Pittsburgh, Pa.
WORKS OFFICE *Canonsburg, Pa.*

"We are very well satisfied with the replies received from our recent advertisement in the Searchlight Section of Metallurgical & Chemical Engineering."

Have You Given This a Trial?

Shall I try it?

JUST remember, thousands of American chemists have asked themselves that question before placing their first order for **Whatman.**

No question any longer—the remarkable uniformity, wet strength and dependability of **Whatman** have earned re-order after re-order. Ask your usual supply house for

WHATMAN
High Grade **FILTER PAPERS**

Guaranteed free from Chlorine and Starch.

No. 1 For general quantitative and qualitative work. Retains Barium Sulphate.

Nos. 2-5 For general qualitative work. Ask for samples.

Acid-Washed Papers

No. 30 Hydrochloric acid treated. Low ash, close texture. For quantitative work.

No. 40 Hydrochloric and hydrofluoric acid treated. Less ash than No. 30. For very accurate quantitative work. Retains finest precipitates.

No. 41 Treated as No. 40. Is more open and filters more quickly. Not recommended for filtering very fine precipitates unless properly precipitated.

No. 42 Has same chemical qualities as No. 40 and 41, but is much harder and extremely close in texture. For use in Filter pumps.

Every other variety of high-grade filter paper is in course of production.

H. Reeve Angel & Co.
120 Liberty St., New York
Sole Representatives for United States and Canada

Empty bottles need no corks

What you take out of a thing depends upon what you put into it.

"Give a man a fortune and he will squander it. Make him earn the money—he will use it."

Value is a state of mind. The things you value the highest—that do you the most good—are the things you buy.

The **profit** you derive from a technical publication depends upon your own mental attitude toward it. Of course, we want you to read Metallurgical and Chemical Engineering whether you subscribe or not.

BUT the sense of **absolute ownership** of a copy of each issue develops that warm mutual interest which enables you to get the greatest benefit out of the constructive, helpful articles which "Met and Chem" contains.

Articles written by the foremost men of the great industries for **your** benefit and **your** profit.

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Metallurgical and Chemical Engineering,
239 West 39th Street, New York.

Enter subscription for Metallurgical and Chemical Engineering to begin at once.

Cross out one of these lines
I enclose $..... herewith.
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Yearly subscription rates: Domestic $3.00; Elsewhere $4.

6-15-16

Laboratory of Studebaker Corporation showing application of Hoskins "FB" Tube Furnaces.

All Up-to-date Laboratories Are *HOSKINS* Equipped

TRADE MARK REGISTERED

The Hoskins electric furnaces shown above are being used for determining the carbon content of steel. These furnaces are capable of producing working temperatures up to 1100° C. (2012° F.) or 100° higher than others. The temperatures are accurately controlled—giving a clean, uniform, non-fluctuating heat.

Hoskins furnaces for laboratory work are built in crucible, tube, and muffle types for use in ash determinations, ignitions of precipitates, incinerations, fusions, combustions, enameling, hardening and annealing small parts, melting alloys and metals, etc.

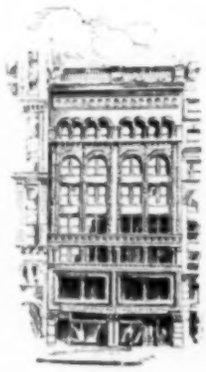
The heating units of Hoskins "FB" furnaces are made of "Chromel" wire and last longer. When damaged these units can be replaced by the operator in a very few minutes.

There is a Hoskins furnace built for every job. If you are in doubt let us recommend the type and size best suited to your own particular needs.

Free Bulletins on request

Hoskins Manufacturing Company
457 Lawton Avenue - DETROIT

CHICAGO Otis Bldg. PITTSBURGH Oliver Bldg. NEW YORK CITY Grand Central Terminal
BOSTON 185 Devonshire St.
Canadian Hoskins, Ltd., Walkerville, Ont.
Central Scientific Company, Chicago
Bausch & Lomb Optical Co., Rochester; Henry Heil Chemical Co., St. Louis; E. H. Sargent & Co., Chicago; A. H. Thomas Co., Philadelphia; Scientific Materials Co., Pittsburgh



WE ARE PREPARED

to take care of any inquiries regarding requirements in the laboratory apparatus and supply line. We call special attention to the following apparatus and articles, which are of interest to Colleges, Schools and other Institutions of learning as well as to the chemical and industrial business world.

SPECIALTIES:

The Lenzmann Micrometer Reader
The Lenzmann Incubator
The Lenzmann-Kober Nephelometer
The Riche Adiabatic Calorimeter.
(Pamphlet on Calorimetry just issued)

LENZMANN NEW YORK XXX

"Lenzmann Insol" Glassware

is the practical Laboratory glass: uniform in shape and thickness, and correct in weight. A trial order will convince you of its acid and alkali-resisting properties. It is the best glass made in America, to replace the German Glass.

Our new **Chemist Apron** (at $2 a piece) is recommended for the protection of the clothes.

Whatman Filter Paper, Balances, Bavarian and Domestic Porcelain Ware, etc., etc.

OUR GENERAL CATALOG SENT ON REQUEST

LENZ & NAUMANN, Inc., 9-11 East 16th St., New York, N. Y.
(Between Fifth Ave. and Broadway)

Eastern Representatives of Leonard Peterson & Co., Chicago, Ill.
Permanent Exhibit of Laboratory Furniture at our showrooms.

Preparedness

—When they reach for the Answer

"I've seen advertisements on that very product in Metallurgical and Chemical Engineering—here is the latest issue."

Most of us have taken part in similar conversations—where the message of some previous advertisement is remembered and the answer sought in the current issue.

It is right at this point that the **every-issue** advertiser profits by his **preparedness.**

—that the **occasional** advertiser **might** be lucky.

—that the **non-advertiser** loses.

Preparedness means—

—to be found when the buyer is looking for you.

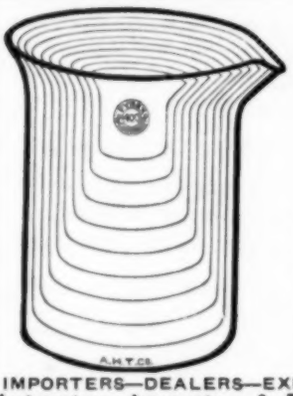
—to insure for yourself, and not others, the business resulting from the interest aroused by your previous advertising.

Is your advertisement in **this** issue? Will it be in the next?

Be Prepared

MERCK'S
BLUE LABEL REAGENTS

are tested according to the book of standards, "Chemical Reagents: Their Purity and Tests." The analysis is on every label. Instruct your dealer to send you Merck's "blue label" goods only.



PYREX 400 CORNING

Stock on hand in our own stock room for immediate shipment

Each article of Pyrex stamped with trademark shown

PYREX

Circular describing Pyrexware sent on request

PYREX 400 CORNING

FLASKS AND BEAKERS

A new resistance glass made by the Corning Glass Works, with extraordinarily low expansion coefficient, and correspondingly great resistance to sudden temperature changes. Experiments show Pyrex glass to be much less soluble in water and acids and about equally soluble in alkalis as compared with the best resistance glass heretofore offered of either American or European make. The low expansion coefficient allows beakers and flasks to be made with thicker wall than usual, thereby greatly increasing the durability of the utensils. These utensils are superior to the best European ware in their resistance to sudden heating and cooling. Of simple chemical composition and contain no metals of the magnesia-lime-zinc group and no heavy metals. In practical laboratory use Pyrex flasks and beakers have proved superior to anything heretofore offered either at home or abroad. Prices are identical with our net duty paid stock prices on the best resistance glass of European make prevailing before the war.

IMPORTERS—DEALERS—EXPORTERS
Laboratory Apparatus & Reagents

ARTHUR H. THOMAS CO. West Washington Square PHILADELPHIA, U.S.A.

Non-poisonous, smokeless, odorless gas for laboratory and industrial purposes

TIRRILL "Equalizing" Gas Machines

Intense heat, brilliant light, low cost of operation, next to no attention. Widely used by laboratories, chemists, experiment stations, metallurgical industries, industrial plants.

Tirrill Gas Machine Lighting Co., 103 E. Park Avenue, New York
Manufacturers of Tirrill High Efficiency Burners for every purpose

Introduce yourself to the men you want to meet

Get Your Card Into the Searchlight

—and thereby get it under the eyes of the men whom you wish to interest. Let them know what you have to offer or what you want.

Our Copy Service Department will assist if you want help in writing your ad. Our readers are sure to furnish you the right audience. The Searchlight is there to concentrate it.

Metallurgical & Chemical Engineering
239 West 39th Street, New York

The Relation of "Brinell Hardness" to the other Physical Properties of Metals

Are you fully posted on the results of the latest investigations of this important subject?

IF NOT—WRITE ME

HERMAN A. HOLZ

50 Church Street
NEW YORK

Manufacturer of the "Brinell Meter"

SEARCHLIGHT SECTION

Machinery for Immediate Delivery

Morse "TYPE A" Filter

Complete with motor, two buckets, all tanks, vacuum pumps, hydraulic crane for handling baskets, capacity 300 tons per 24 hours. In excellent condition.

Portland Filter

One Portland filter, complete specifications on request.

Electric Hoists

1—50-hp., 3-phase, 60-cycle, 440-volt
1—35-hp., 3-phase, 60-cycle, 440-volt
1—20-hp., 3-phase, 60-cycle, 440-volt
1—15-hp., 3-phase, 60-cycle, 440-volt
1—10-hp., 3-phase, 60-cycle, 440-volt
2—7½-hp., 3-phase, 60-cycle, 440-volt

Crushers

1—5x7 steel roll jaw crusher
1—7x10 Blake crusher
1—7x11 Dodge crusher
1—7x16 Sampson crusher
3—9x15 Blake crushers
1—9x16 Western Steel crusher
1—No 3 Aurora crusher
1—No. 2 Gardner crusher
1—No. 1 D. Gates crusher
1—No. 3 D. Gates crusher
1—Size "C" Comet crusher

Rolls

1—Set 6x10 Sample rolls
1—Set 12x20 McFarlane rolls
2—Sets 14x27 Davis rolls
1—Set 10x30 Allis-Chalmers rolls
1—Set 16x36 Davis rolls
1—Set 16x40 Colorado Iron Wks. rolls
1—Set 3x10 Triplex rolls
1—Set 5x18 Triplex rolls
3—Sets 6x24 Triplex rolls

Belt-Driven Air Compressors

1—8x10 Hall Single
1—10x12 Sullivan single
1—12x10 Blaisdell single
1—12x10 Ingersoll-Sergeant single
1—18 and 10x10 Clayton, 2-stage
1—18 and 10x12 Laidlaw-Dunn-Gordon, 2-stage
1—24¼ and 14¼x14 Ingersoll-Rand, 2-stage
3—28 and 17x24 Ingersoll-Rand, 2-stage

Tube and Ball Mills

1—5x24-ft. Tube mill
1—5x22-ft. Abbe tube mill
1—48-in.x16-ft. Abbe tube mill
1—48-in.x12-ft. Traylor tube mill
1—6x9-ft. Gates Ball mill
1—5x7 Standard Ball mill
1—5x4 Standard Ball mill
1—4x3 Standard Ball mill

Pulverizers and Mills

5—5-ft. Huntington mills
2—6-ft. Huntington mills
1—50-in. Standard Pulverizer

Water Wheels

1—18-in. Morgan Smith turbine
1—35-in. Samson turbine
1—3-ft. Hug water wheel
1—4-ft. Pelton water wheel
1—5-ft. Pelton water wheel

Send for our complete machinery list

The Morse Bros. Machinery & Supply Co.
1732 Wazee Street - - - - - - Denver, Colo.

FOR SALE

Complete Equipment for the Manufacture of

Grease and Blending Lubricants

6—Bowser 2000 gallon capacity Oil Storage Tanks, each with individual Motor Driven Remote Control Pump and Automatic Self-Registering Meter.
1—500 gallon Saponifying or Mixing Kettle, steam jacketed, conical bottom; heavy cast steel top head with clamp cover.
1—High Speed Circulating Shredder attached to bottom of the above kettle.
1—500 gallon Saponifying or Mixing Kettle, conical bottom, with pipe coils in 3 sections inside, extending up to enlarged coaming; includes enclosed Vapor Hood.
1—Day 2 barrel Dough Mixer.
1—60 gallon Oil Mixing Tank.
1—45 gallon Mixing Tank.
1—45 gallon Mixing and Saponifying Tank, steam jacketed.

All Mixing Tanks have Agitators and Independent Clutch or Countershaft drive

1—Graphite Storage and Weighing Tank with Pneumatic Vibrating Sifter.
1—10 gallon Stuart & Petterson Steam Jacketed Kettle.
6—Metal Tanks, various sizes.
1—Soap Chipping Machine.
1—Howe Power Spice Mill.
1—Drying Cabinet.

Will sell complete or separate items.
In operative condition at the plant of

The American Brake Company
1932 North Broadway, St. Louis, Mo.

Four Second-hand Vertical DRY VACUUM PUMPS

piston type, duplex and double acting, built by the Deane Steam Pump Company of Holyoke, Mass.

Cylinders of acid bronze, diameter 20", stroke 18".

Each with cut cast iron spur gear and cut steel pinion, steel pinion shaft, ring oiling bearings, Moore & White cutoff coupling and belt pulley.

In good running condition. On account of change in method, machines not needed.

Will Make an Attractive Price

HAMMERMILL PAPER CO.
Erie, Pa.

CHIEF CHEMIST

Situation as chief chemist at **Norsk Hydro-Elektrisk Kvaelstofaktieselskap** (Norwegian Hydroelectric Nitrogen Stock Company) is vacant. A chemist of Norwegian nationality is wanted as soon as possible. The chief chemist will reside in Kristiania. Salary according to agreement. Applications with copies of testimonials and recommendations, also references, may be addressed to the office of

Norsk Hydro,
Solligaten 7, Kristiania, Norway

We Pay Highest Prices For Scrap Platinum

Now is the time to dispose of platinum—do not wait until the price goes lower. Estimate or remittance by return mail. Reference if desired.

Miller Smelting & Refining Co.
Ellastone Bldg., E. Fourth St. & Prospect Ave., Cleveland, Ohio
We also buy palladium and mercury and refine gold, silver and other precious metals.

This is a good time to sell your
PLATINUM SCRAP
Prices Are High

We purchase scrap platinum at the highest market prices—Cash on delivery.

THE H. A. WILSON CO.
97 Chestnut St., Newark, N. J.

Get Your Wants into the Searchlight

SEARCHLIGHT SECTION

Get your Wants into the Searchlight

ADVERTISING RATES

Under "Positions Wanted," including Salesmen looking for new connections, Evening Work Wanted, Side Line Wanted, etc., undisplayed advertisements cost **two cents a word**, minimum charge 50 cents an insertion, **payable in advance.**

Under "Positions Vacant," including Agents and Agencies Wanted, Representatives Wanted, Salesmen Wanted, Partners Wanted, Desk Room Wanted or For Rent, Business Opportunities, Employment Agencies, and Miscellaneous For Sale, For Rent, and Want ads; also Auction Notices, Receivers' Sales, Machinery and Plants For Sale or Wanted (with one line of display heading), undisplayed advertisements cost **three cents a word**, minimum charge $1.50 an insertion.

If replies are in care of any of our offices, allow five words for the address.

All advertisements for bids (Proposals) cost $2.40 an inch.

ADVERTISEMENTS IN DISPLAY TYPE

cost as follows for single insertions:

⅛ p. (1⅛x3⅜ ins.)	$5.00	1 in. (1x2⅛ ins.)	$3.00
¼ p. (2⅛x3⅜ ins.)	10.00	4 inches (4x2⅛ ins.)	11.60
½ p. (5x3⅜ or 2⅛x7 ins.)	20.00	8 inches (8x2⅛ ins.)	22.40
½ p. (10¼x3⅜ or 5x7 ins.)	40.00	15 inches	40.50
1 page (10¼x7 ins.) 30 inches	$80.00		

For space to be used within one year, to be divided to suit requirements of advertiser, provided some space is used in each issue following first insertion:

3 pages	$75 a page	12 pages	$60 a page
6 pages	70 a page	18 pages	55 a page
9 pages	65 a page	24 pages	50 a page

In replying to advertisements, do NOT enclose original testimonials, drawings or photographs that you may want returned. Advertisements for men often produce several hundred applications and no employer can be expected to read all of these carefully and return the papers or applications of those in which he is not interested. State your experience and qualifications in as concise and neat a manner as possible and enclose COPIES of your testimonials.

When advertising machinery, use your own name and address—or a local address of some kind—so that the readers can wire direct and get quick replies. We advise also that you state in your advertisement the present location of plant that is offered for sale, or point of delivery provided you are in the market for equipment.

FOR SALE

Iron Ore Land

For sale or lease on royalty, several thousand acres of iron ore in Southern Illinois. High grade. Adjacent to navigable water. Address Charles E. Jackson, Trustee, Middletown, Conn., or Arthur R. McKernan, Adm'r, Elizabethtown, Illinois.

Vacuum Pan for Sale

One copper vacuum pan. Capacity: Evaporation per twenty-four hours, 20,580 gallons; in excellent condition; now in use but too small for us. For complete detail write Armour & Co., Purchasing Department, Chicago, Ill.

Books for Sale

Portion of the library of mainly scientific works from the research laboratory of the late "Carbide Willson." Send for price list. Address Max M. Haff, Ottawa, Can.

Generators for Sale

Two 1200 kw., 25 cycle, 6600 volt, 3 phase General Electric alternators with 30 in. x 50 in. x 60 in Allis-Corliss horizontal cross-compound engines; one 800 kw., 600 volt direct current generator with 32 in. x 60 in. simple Allis-Corliss engine. United Railways Co., 3869 Park Ave., St. Louis, Mo.

"24" Gauge Locomotives and Cars

1— 9 ton Shay geared locomotive.
1—14 ton Shay geared locomotive.
2—20 ton Shay geared locomotives.
1—33 ton Shay geared locomotive.
20—All metal twin Hopper bottom dumps.

All first class condition. In stock here. Gauge can be changed if desired.

ZELNICKER IN ST. LOUIS

RAILS MACHINERY TANKS

MISCELLANEOUS WANTS

Vacuum Evaporator Wanted

A triple effect vacuum evaporator. Must be of copper and in good working order. Box 656, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

Balances Wanted

Bullion or Silver Balances; one pair second hand Troy Silver Balances, one thousand ounce capacity. Must be in good condition with weights. In answering this ad state make of Balance, condition, and if *all* weights are included. Box 696, Met. & Chem. Eng.

MISCELLANEOUS WANTS

Rotary Furnace Laboratory

Equipped especially for the study upon a commercial scale of furnace problems such as potash from feldspar, burning lime, nodulizing ores, oxidizing and desulphurizing ores and chemicals, etc. Equipment includes 2' x 20' rotary kiln, fired with oil, gas or powdered coal, crushing and pulverizing machinery; also well equipped chemical laboratory. Open for limited engagement upon favorable terms. Box 643, Met. & Chem. Eng., Real Estate Trust Bldg., Phila., Pa.

Send Us Your Waste Samples

Do you know your tailings or waste dumps do not carry values in some valuable metals or do you guess it? Why not send us a sample with request for cost of finding out? Box 702, Met. & Chem. Eng.

Oxygen

Important French firm wishes to buy machinery for production of oxygen. Reply to Mr. Vernier, 5 Villa Stendhal, Paris, France.

Dryers and Condensers Wanted

Vacuum shelf dryers and condensers wanted. Give full particulars as to dimensions, maker's name and condition.

Box 699, Met. & Chem. Eng.

BUSINESS OPPORTUNITIES

Earn $20,000 a Month

A partner wanted with $5,000, money to be used to get led silver ore from 8 ft. ledge to smelter. A big paying investment. Property should earn $20,000 a month from start. D. J. Hancock, M.E., 715 Olive St., Seattle, Wash.

Partner Wanted

Responsible partner in good standing to cooperate with advertiser in developing manganese ore deposits Eastern Canada and also in producing ferro-manganese by electric smelting from the ore. I have the ore, experience and knowledge necessary for erection of plant. Prefer co-operation with large reliable concern with knowledge of marketing product. Box 713, Met. & Chem. Eng.

POSITIONS WANTED

ALUMINA—Ten years' experience in the purification and extraction of alumina. Either permanent or consulting position desired. Box 671, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

CHEMICAL engineer, 35 years' practical and research experience, wishes position as superintendent or assistant manager with well-established chemical manufacturing concern. Now employed but desires change. Only good offer considered. Box 640, Met. & Chem. Eng.

CHEMICAL engineer with three years' experience in making Sulphuric Acid Explosives and the analysis of acids in laboratory desires to change position. Best references furnished. Nothing but good proposition considered. Box 697, Met. & Chem. Eng.

CHEMICAL engineer, B.S., 1915, wishes position in plant or research or with this in view. Experienced in general and metallurgical laboratory (nonferrous) work. Now employed and completing graduate year of study. Good references. Box 704, Met. & Chem. Eng., Real Estate Trust Bldg., Phila., Pa.

CHEMICAL engineer, graduate, wide general experience in research, metallurgical, manufacturing, physical, electro-chemical lines, etc., organic and inorganic; many years chief chemist large smelter and mines. Full particulars and references. Box 709, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

CHEMIST—28, laboratory and factory experience, at present employed, wishes position with prospects for advancement. Box 718, Met. & Chem. Eng.

CHEMIST—27, graduate, with good experience, wishes position. New York or suburb preferred. Box 717, Met. & Chem. Eng.

CHEMIST, graduated, over one year's experience, mostly in research work. Lately working at the production of dyes, wishes position; moderate salary. Box 595, Met. & Chem. Eng.

CHEMIST having good judgment from wide experience in 18 years' research work, original investigations, examinations of processes, patents, inventions. Close association with electro-chemical-metallurgical manufactures. Has the ability to evolve new processes. Twelve years in present position. Permanent employment not essential. Box 618, Met. & Chem. Eng.

SEARCHLIGHT SECTION

POSITIONS WANTED

CHEMIST, 6 years' experience in laboratory work and concentration of copper ores, including flotation, desires position of responsibility. Graduate from well known mining college. Box 687, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

CHEMIST and metallurgist, 37, experienced in designing and equipping laboratories. Also experienced in the electric furnace. At present employed, wishes position with established firm. Box 706, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

CHEMIST, age 23, year's experience in steel non-ferrous metals and allied work. University graduate, desires position in plant or laboratory, not necessarily in United States. Good business training. Will consider sales proposition. References from previous employer, moderate salary with opportunity. Box 707, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

CHIEF chemist—A young man experienced in alloy steels, now non-ferrous alloys and all work connected. Strictly up to date. Can control laboratory to advantage. Employed as chief chemist for large corporation. Wish to change where hard work and results will bring advancement. Box 650, Met. & Chem. Eng.

ELECTRICAL and metallurgical engineer, age 25. Holds degrees of E.E. and Met. E. from prominent university. Thoroughly trained in electrical engineering, metallurgy, in organic chemistry, electro-chemistry and electro-metallurgy. Desires position with opportunity for advancement. At present in charge of electrolytic plant. Box 619, Met. & Chem. Eng.

ELECTRO-CHEMICAL graduate, M.I.T., 1915, age 23, unmarried, one year as chemist in lead and copper smelter, good references, wishes position in engineering, manufacturing, or research line offering bigger future. Present salary $1,200. Box 691, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

ENGINEER experienced in manufacture dyestuffs, aniline, benzene and acids, dye bases and finished products. Box 700. Met. & Chem. Eng.

IRON and steel chemist, and malleable iron metallurgist, capable of taking entire charge of iron and steel laboratory, desires permanent position. Will work under chief chemist. Exceptional references. Now employed in Canada in charge of rapid control work, in making shell steel, but open for immediate engagement. American, age 30, married. Box 690, Met. & Chem. Eng.

POSITIONS WANTED

METALLURGICAL and chemical engineer, now employed by large concern. Expert in plant efficiency. Have you an executive position? Box 715, Met. & Chem. Eng.

MUST connect with some responsible concern. I have an intimate practical acquaintance with everything from the ash pit of a boiler room to the solution of hard electro-chemical problems. Original and inventive. Can use what is at hand. Skillful with machine tools. Box 684, Met. & Chem. Eng.

SUPERINTENDENT wants position as superintendent or assistant superintendent. Having had experience in electrolytic alkali work. Good general experience and college training. Accustomed to plant management and handling men. Is at present employed but desires a change. References. Box 693, Met. & Chem. Eng., Real Estate Trust Bldg., Philadelphia, Pa.

TECHNICAL and analytical chemist, age 30, experienced in electro-metallurgy, handling furnaces and men. Formerly chief chemist of large smelter, now department superintendent, in present plant 6 years. Box 680, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

TURNINGS from brass time fuse forgings. I have a thoroughly practical process to melt this material with a loss of 5% or less. If this means a saving in your foundry or refinery, please communicate. Box 705, Met. & Chem. Eng.

POSITIONS VACANT

CHEMICAL engineer familiar with manufacturing liquid chlorine and bleaching powder is wanted for works situated abroad. Box 711 Met. & Chem. Eng.

FOREMAN with experience in manufacturing liquid chlorine and bleaching powder is wanted for works abroad. Box 712, Met. & Chem. Eng.

Electro-Metallurgist Wanted

Excellent position open for high class electro-metallurgist. Must have both technical knowledge and practical experience in production of alloys. Must understand operation, construction and maintenance of electric furnaces. Executive ability desirable. Box 698, Met. & Chem. Eng., Real Estate Trust Bldg., Phila., Pa.

AGENTS AND SALESMEN

Wants Position as Salesman

Chemist, technical graduate, with unusual qualifications for the sales end of the chemical business, wishes to connect with a firm where advancement would be proportionate to results. Write "Sales," 767 Dawson St., N. Y. City.

EMPLOYMENT AGENCIES

THE RODGERS' LOYAL CLUB

organized by paroled inmates of the New York State Reformatory at Elmira, New York, for the purpose of self-help, can furnish male help to employers in need of young men from 17 to 30 years of age.

As an employer of labor, will you help in this effort at rehabilitation by giving one or more of our members employment?

We can furnish almost any kind of ability required, from an expert accountant to ordinary laborer.

Hundreds of these young men are making good in this city today through co-operation of business men in giving them honest employment.

Are you interested enough to help in this manner to prevent crime and to save from criminal lives the really worthy men we could send to you?

If so, please address

H. B. RODGERS
Chief Parole Officer
Elmira Reformatory
135 East 15th St., New York City
Telephone 1470 Stuyvesant

Get Your Wants into the Searchlight

Satisfied

"I received four replies and have just closed a deal for a very satisfactory position."

Very truly yours,
R. E. B.

CHEMICAL engineer and electro-metallurgist, holds degrees of M.S. and Ch.E. from two Middle West State universities. Thoroughly trained in inorganic physical and electrical chemistry, in metallurgy and electro-metallurgy. Desires position in chemical engineering or metallurgical work with opportunity for advancement. References. Now employed. Box 471, Met. & Chem. Eng., 1570 Old Colony Bldg., Chicago, Ill.

Published twice at $1.05 per insertion

If you are looking for a job make it known through the

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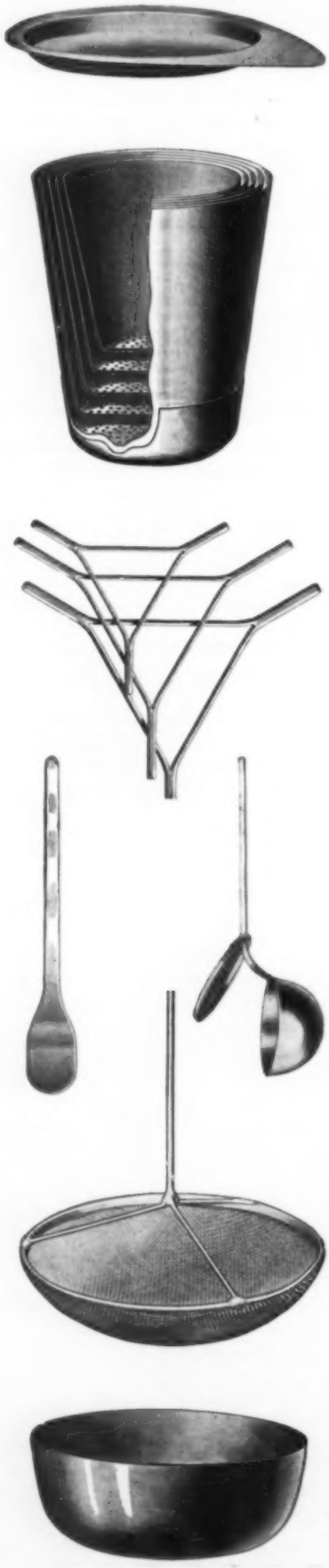

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Harbison-Walker Refractories Co.
Kieselguhr Co. of America.
Maurer, Hy., & Son.

Fireproof Building Materials
Asbestos Protected Metal Co.

Flasks
Fry, H. C., Glass Co.

Fluorspar
Lavino, E. J., & Co.

Foundry Supplies
Electric Smelting & Alum. Co.

Furnace Cores, Elec.: *Alundum*
Norton Co.

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Kieselguhr Co. of America.
Maurer, Hy., & Son.

Furnace Linings, Graphite
Acheson Graphite Co.

Furnace, Chloridizing and Sulphating
Wedge Mechanical Furnace Co.

Furnaces, Cupola, Foundry
Power & Mining Machy. Co.

Furnaces, Electric
Metal Refining or Melting
Crowley, J. A., Co.
Hamilton & Hansell.
Leavitt, C. W., & Co.

Furnaces, Electric, Lab'y
Brown Instrument Co.
Eimer & Amend.
Electric Htg. Apparatus Co.
Engelhard, Chas.
Hoskins Mfg. Co.

Furnaces, Heat Treating
Electric Htg. Apparatus Co.
Engelhard, Chas.
Hoskins Mfg. Co.
Rockwell, W. S., Co.
Wedge Mechanical Furnace Co.

Furnace Hoists
Brown Hoisting Machinery Co.

Furnaces, Melting:
Oil, Gas or Powdered Coal
Rockwell, W. S., Co.

Furnaces, Muffle
Electric Htg. Apparatus Co.
Hoskins Mfg. Co.
Improved Equipment Co.
Wedge Mechanical Furnace Co.

Furnaces, Roasting
Pacific Foundry Co.
Wedge Mechanical Furnace Co.

Furnaces, Smelting
Colorado Iron Works Co.
Koven, L. O., & Bro.
Pacific Foundry Co.
Traylor Eng. & Mfg. Co.
Wedge Mechanical Furnace Co.

Furnaces, Sulphur
Pacific Foundry Co.
Wedge Mechanical Furnace Co.

Gas Filters
Simon, Buhler & Bauman.

Gas Plants
Tirrill Gas Mach. Lighting Co.

Gas, Oxygen or Hydrogen
International Oxygen Company.

Gas Producers
Improved Equipment Co.
Morgan Const. Co.
Smith Gas Power Co., The.

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Simon, Buhler & Bauman.

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Bristol Co., The.
Taylor Instrument Co.
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Glazing Construction
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Hardness Testers
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Webster & Co., Warren.

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P. H. and F. M. Roots Company.

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Raymond Bros. Imp. Pulv. Co.
Williams Patent Crusher & Pulverizer Co.

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Duriron Castings Co.
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Lenz & Naumann.
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Towers, Acid Proof
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Changes of copy for standing advertisements, where proof is not necessary, must be received not later than eight days before date of issue.

New Advertisements (not changes of copy) received five days before date of issue can usually be inserted.

Searchlight Advertisements (Wants, For Sale, etc.) received four days before date of issue will be published if space is then available.

If Proofs are Required before printing, changes of copy should be in our hands two weeks in advance of date of publication. The paper is dated the 1st and 15th, but is out the day before.

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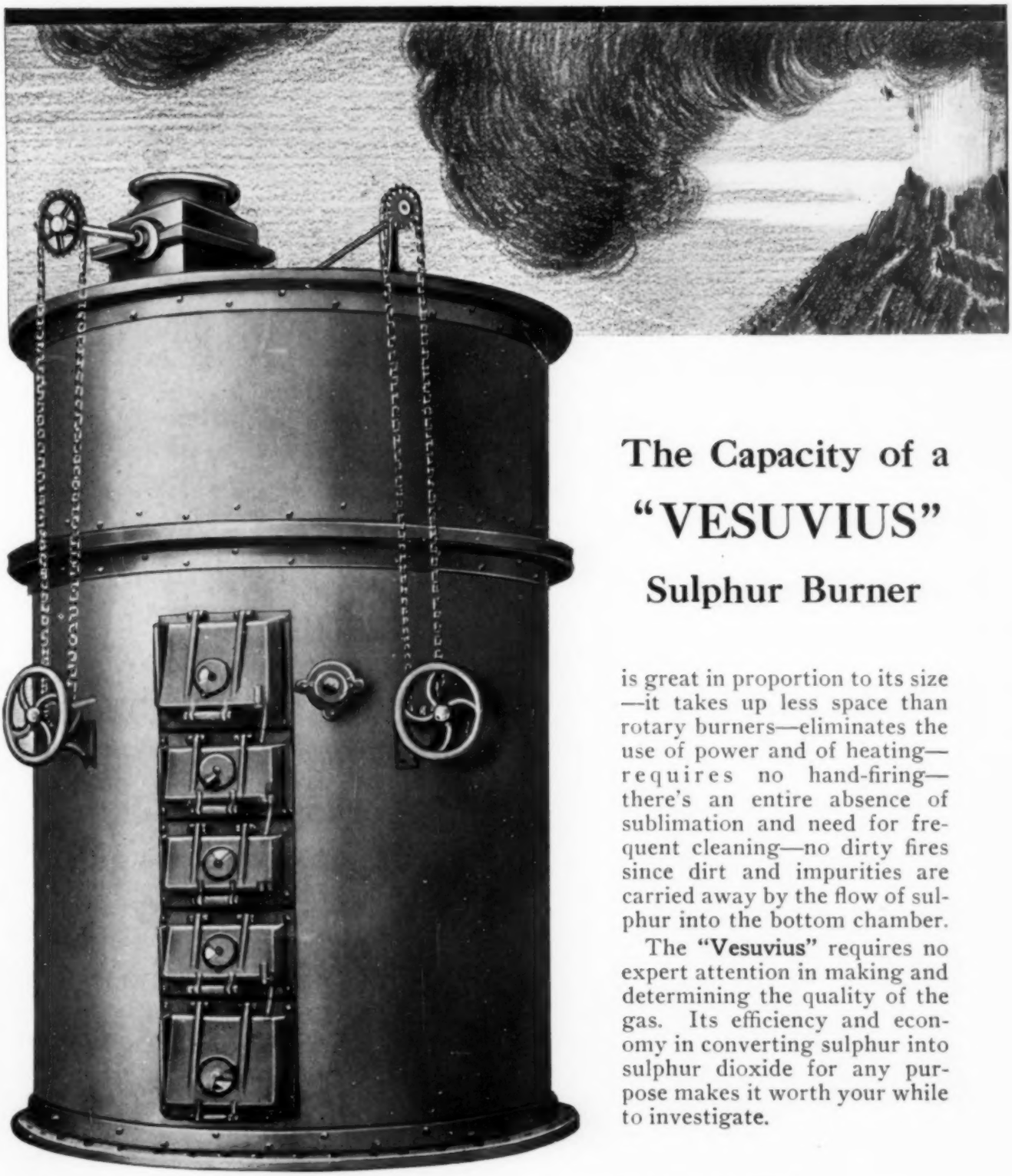

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